2006 SUMMARY OF ENGINEERING RESEARCH

A Report of Activities during 2005

This report is part of the larger 2006 Summary of Engineering Research, available on the Web at www.engr.uiuc.edu/research and on CD-ROM. The Summary of Engineering Research represents the extensive engineering research program conducted in 2005 at the University of Illinois at Urbana-Champaign. Detailed statistics about research in the College of Engineering are included in the Directory of Engineering and Engineering Technology Programs and Research, published by the American Society for Engineering Education, Washington, D.C.

How to use the Summary of Engineering Research: Research projects are listed by title, followed by the names of the investigators and the sponsoring agencies. Projects are sorted by major topic areas. Project descriptions are brief. Additional information on each project may be obtained from the investigator in charge (denoted by an asterisk). Mailing addresses are provided on the introductory page.

How to obtain publications: Please consult academic and public libraries for the journal articles, papers, and books listed in this report. Information about technical reports is available from the Engineering Documents Center, Grainger Engineering Library Information Center, 1301 West Springfield Avenue, Urbana, IL 61801, USA. To search the center's collection on the Internet, please visit the website at search.grainger.uiuc.edu/top. Copies of theses can be found at the University of Illinois Library, www.library.uiuc.edu, or may be purchased from University Microfilms, 300 Zeeb Road, Ann Arbor, MI 48106, USA, www.umi.com.

The 2006 Summary of Engineering Research is produced by the Office of Engineering Communications, University of Illinois at Urbana-Champaign.

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Please send queries and comments about the 2006 Summary of Engineering Research to the Engineering Communications Office, 303 Engineering Hall, MC-266, 1308 West Green Street, Urbana, IL 61801, USA, or email research@engr.uiuc.edu.

Abbreviation key for College of Engineering departments and major labs:

- Advanced Transportation Research and Engineering Laboratory (ATREL)
- Aerospace Engineering (Aerosp. Engr.)
- Agricultural and Biological Engineering (Ag. & Biol. Engr.)
- Bioengineering (Bioengr.)
- Chemical and Biomolecular Engineering (Chem. & Biomol. Engr.)
- Civil and Environmental Engineering (Civil & Environ. Engr.)
- Computer Science (Comput. Sci.)
- Coordinated Science Laboratory (CSL)
- Electrical and Computer Engineering (Elect. & Comput. Engr.)
- Frederick Seitz Materials Research Laboratory (FS-MRL)
- General Engineering (Gen. Engr.) or Industrial & Enterprise Systems Engineering (Indus. & Enter. Syst. Engr.)*
- Materials Science and Engineering (Mat. Sci. & Engr.)
- Mechanical and Industrial Engineering (Mech. & Indus. Engr.) or Mechanical Science and Engineering (Mech. Sci. & Engr.)*
- Micro and Nanotechnology Laboratory (MNTL)
- Nuclear, Plasma, and Radiological Engineering (Nucl., Plasma, & Radiol. Engr.)
- Physics
- Theoretical and Applied Mechanics (Theoret. & Appl. Mech.)*

*In August 2006, the Industrial Engineering program was merged with the General Engineering Department, which became the Industrial and Enterprise Systems Engineering Department. The Theoretical and Applied Mechanics Department merged with the Mechanical and Industrial Engineering Department, which became the Mechanical Science and Engineering Department. Please check department links at www.engr.uiuc.edu for current faculty lists.

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During the past 55 years, the Coordinated Science Laboratory (CSL) has gone through several transformations and expansions in its research focus. Started as a NASA-supported, multidisciplinary control systems laboratory in the 1950s, CSL evolved into a world-class, military-supported electronics research facility in the 1970s and 1980s, and then became what it is today: a premier national laboratory in information technology and telecommunications research.

Through these decades, the task at CSL has always been to look ahead 5 to 20 years. Today, interdisciplinary teams research innovative computing, communications, signal processing, and control technologies—the infrastructure that makes seamless wireless/wireline technology and Internet applications, such as e-commerce and distance learning, possible. At CSL, design, implementation, interaction, and evaluation issues are investigated at every level, from devices to circuits and systems and from algorithms to networked architectures and software.

Support for research programs at CSL is extensive and broadly based, with significant investments from many federal agencies such as the Defense Advanced Research Projects Agency (DARPA), National Science Foundation (NSF), and the Office of Naval Research and from many major corporations, including AMD, AT&T, Boeing, Cisco, Hewlett-Packard, IBM, Intel, Microsoft, Motorola, Nokia, and Sun. In addition, major corporate research centers and national laboratories, such as the Motorola Corporate Research Laboratories and the Jet Propulsion Laboratory, work in synchrony with CSL faculty on a variety of projects.

CSL research is led by approximately 90 faculty members from 11 departments, and assisted by 350 graduate students and 50 undergraduates. CSL maintains relationships with more than 40 industrial partners and has strong links with the departments of Aerospace Engineering, Mechanical and Industrial Engineering, and Mathematics. CSL is located primarily in its own building, with additional facilities in the Engineering Sciences Building, Beckman Institute for Advanced Science and Technology, and the Frederick Seitz Materials Research Laboratory.

The future is difficult to predict, but one thing is certain: for any of our technological dreams to unfold, an underlying information technology infrastructure—fast, adaptive and responsive, highly reliable, trusted, and secure—must be in place. The ultimate research goal of CSL is to make this infrastructure a reality.

CSL research areas include the following:
- Circuits
- Communications
- Computational Electronics
- Cryptography and Information Protection
- Decision and Control
- Physical Electronics
- Reliable and High-Performance Computing
- Signal and Image Processing
- Space Science and Remote Sensing
- Supercomputing Research and Development
- Surface Studies
- Thin Film Electronics

Faculty associated with CSL are listed below:

**Department of Aerospace Engineering**
- N. Neogi
- P. Voulgaris

**Department of Civil and Environmental Engineering**
- L. Liu

**Department of Computer Science**
- V. Adve
- G. Agha
- R. Campbell
- G. Dejong
- C. Gunter
- K. Nahrstedt
- L. Sha

**Department of Electrical and Computer Engineering**
- I. Adesida
Faculty and Their Interests

John R. Abelson
Plasma-assisted deposition of semiconductor, dielectric, and conductive thin-films for electronic applications; the physics and chemistry of film growth; fabrication of photovoltaic cells and thin-film transistors for macroelectronics

Ilesanmi Adesida
Electronic and transport properties of ultra-low dimensional semiconductor structures, advanced processing methods for electronic devices, high-speed optoelectronic devices and integrated circuits, radiation effects

Vikram Adve
Compilers, software reliability, performance analysis, computer architecture

Gul A. Agha
Developing new abstractions for building open distributed systems and reasoning about their behavior, parallelism, coordination, real-time behavior

Narendra Ahuja
Computer vision, robotics, image processing, sensors, pattern recognition, virtual environments, intelligent interfaces

Jont Allen
Speech recognition based on the articulation index and aspects of information theory

Leslie H. Allen
Thin-film physics, microelectronic processing, interfaces, nanoscale, size-dependent material properties, nanocalorimetry

Andrew G. Alleyne
Automotive systems, control systems

Tamer Basar
Information technology research; control over wired and wireless networks; robust identification and control; dynamic games and stochastic teams; nonlinear and adaptive robust control; decentralized detection and estimation; routing, pricing, and congestion control; modeling and control of communication networks; mobile computing; incentive mechanisms through pricing; neural networks-based identification and control; applications of control and game theory in economics

Stephen G. Bishop
Optical and electrical characterization of crystalline and amorphous semiconductors and semiconductor nanostructures, compound semiconductors: GaAs, InP, AlGaAs, ZnSe, SiC, defects in semiconductors, isoelectronic defects, rare earth-doped chalcogenide glasses and GaN. Experimental techniques: photoluminescence, nuclear magnetic resonance, electron spin resonance, magneto-optics, photoemission, infrared spectroscopy

Richard Blahut
Communications, signal processing, information theory, optical recording

Yoram Bresler
Biomedical imaging systems; statistical signal and image processing; inverse problems; statistical pattern recognition; sensor-array processing

Donna J. Brown
Asynchronous learning technologies and environments; WWW-based education; VLSI placement and routing; parallel and distributed algorithms and architectures; analysis and design of algorithms, with a particular interest in approximation algorithms; graph theory

David Cahill
Epitaxial growth, scanning tunneling microscopy, ion-surface interactions, thermal properties of thin films, strained layer heterostructures

Roy H. Campbell
Security, distributed operating systems, ubiquitous computing

Andreas Cangellaris
Numerical techniques for electromagnetic modeling and simulation, microwave circuit design, speed VLSI interconnects, electronic packaging, electromagnetic computer-aided design for high-speed digital and RF/microwave electronics, antenna modeling, optoelectronic interconnects, electromagnetic modeling for nonlinear optics

Scott Carney
Optical physics, including imaging, near-field microscopy, classical and quantum coherence theory, beam propagation, fundamental issues of energy conservation, mathematical methods in inverse scattering and the propagation of light
<table>
<thead>
<tr>
<th>Name</th>
<th>Research Areas</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nicholas Carter</td>
<td>Architectures that combine programmable processors and reconfigurable logic, computing using nanotech devices, design techniques to integrate computation and sensing</td>
</tr>
<tr>
<td>Keh-Yung Cheng</td>
<td>Molecular beam epitaxy technology, optoelectronic integrated circuits, high speed devices, <em>in situ</em> fabrication of nanostructures, quantum wire lasers, vertical cavity surface emitting lasers, Sb-based IR detectors and electronic devices</td>
</tr>
<tr>
<td>James J. Coleman</td>
<td>Semiconductor lasers, optoelectronics, epitaxial growth</td>
</tr>
<tr>
<td>Gerald DeJong</td>
<td>Artificial intelligence</td>
</tr>
<tr>
<td>Minh Do</td>
<td>Image and multidimensional signal processing, wavelets, imaging, multiscale geometric analysis, visual information representation</td>
</tr>
<tr>
<td>Geir E. Dullerud</td>
<td>Control systems, dynamic systems</td>
</tr>
<tr>
<td>James G. Eden</td>
<td>Ultraviolet and visible lasers and laser spectroscopy, microcavity plasma devices and arrays, micro- and nanophotonic resonators; optical physics, including femtosecond laser spectroscopy and technology, and the interaction of intense optical fields with matter, laser magnetometry</td>
</tr>
<tr>
<td>Gert Ehrlich, Emeritus</td>
<td>Surface studies including crystal growth on the atomic level, atomic interactions and clusters</td>
</tr>
<tr>
<td>Matthew Frank</td>
<td>Computer system architecture, parallel computing, program analysis, concurrency control, online algorithms</td>
</tr>
<tr>
<td>Steven J. Franke</td>
<td>Development and application of radar and signal processing techniques for remote sensing in the middle and upper atmosphere; application of tomographic imaging to the middle and upper atmosphere using arrays of ground-based sensors and low-earth orbit satellites; low-power wireless RF communications; high efficiency linear power amplifiers for RF communications and radar applications</td>
</tr>
<tr>
<td>Chester S. Gardner</td>
<td>Optical communication, laser altimetry, laser remote sensing and ranging, laser guide stars, adaptive optics</td>
</tr>
<tr>
<td>Christoforos Hadjicostis</td>
<td>Systems and control, error control coding, fault diagnosis and tolerance in dynamic systems, testing and verification, discrete event systems, algebraic systems, coding and graph theory</td>
</tr>
<tr>
<td>Bruce E. Hajek</td>
<td>Communication networks information theory, computer networks stochastic analysis, optimization wireless communication</td>
</tr>
<tr>
<td>Mark Hasegawa-Johnson</td>
<td>Acoustic phonetics, audio signal processing and speech recognition, speech and auditory physiology</td>
</tr>
<tr>
<td>Karl Hess</td>
<td>Hot carriers in semiconductors, electronic transport in heterojunction structures and superlattices, numerical simulation of semiconductor devices (supercomputing applications), quantum transport in mesoscopic systems, laser diode simulation, molecular and electron nanostructures, theory and simulation, deuterium processing and MOS reliability, quantum computing, theorem of Bell</td>
</tr>
<tr>
<td>Thomas S. Huang</td>
<td>Image processing, image compression, computer vision, human computer interaction, image and video databases</td>
</tr>
<tr>
<td>Wen-Mei Hwu</td>
<td>Architecture, compilation and microarchitecture of high performance parallel computer systems</td>
</tr>
<tr>
<td>Ravishankar K. Iyer</td>
<td>Design and evaluation of reliable and secure networks and systems, computer measurement and modeling, dependability and security validation and benchmarking</td>
</tr>
<tr>
<td>Douglas L. Jones</td>
<td>Digital signal processing, time-varying and time-frequency analysis, signal processing for communications, binaural hearing aids, signal processing for MEMS</td>
</tr>
<tr>
<td>Farzad Kamalabadi</td>
<td>Remote sensing and imaging, multidimensional signal and image processing, signal reconstruction and tomography, ionospheric and space physics</td>
</tr>
</tbody>
</table>
Ralf Koetter
Practical and theoretical aspects of coding theory, complexity, algorithms, communication systems, networks

Philip T. Krein
Power electronics, electric machinery and electromechanics, electric and hybrid vehicle systems

Erhan Kudeki
Radar remote sensing; atmospheric winds, waves, and turbulence; ionospheric plasma instabilities; incoherent scatter electric field measurements; midlatitude field aligned irregularities and meteor trails

P. R. Kumar
Wireless networks, sensor networks, convergence of control, communication and computation, semiconductor manufacturing, manufacturing systems, machine learning, adaptive systems, control, stochastic systems

Jean-Pierre Leburton
Theory of semiconductor devices, modeling and simulation of nanostructures, electronic and optical properties of heterostructures and low dimensional systems, transport in quantum structures, electronic properties, charging effects in quantum dots and nanocrystals, spin effects in nanostructures, quantum computation and quantum information processing, nano-bio-electronics

Stephen Levinson
Speech processing, language acquisition, natural language understanding, speech synthesis

Zhi-Pei Liang
Magnetic resonance imaging, pattern recognition, statistical learning, bioinformatics

Daniel Liberzon
Nonlinear control theory, analysis and synthesis of hybrid dynamical systems, systems with imprecise measurements and/or modeling uncertainty, stochastic differential equations and control

Liang Y. Liu
Construction project controls, productivity analysis and improvements, information technology, sensors and field data collection, construction modeling and simulation

Michael C. Loui
Computational complexity theory, ethics in engineering and computing, scholarship of teaching and learning

Steven Lumetta
Optical network architecture, computer architecture, cluster computing, parallel computing, user-level communication, validation and reliability

Joseph W. Lyding
Scanning tunneling microscopy and spectroscopy, STM-based nanolithography and nanofabrication, silicon-based molecular electronics, carbon nanotubes and carbon-based nanotechnology merged with silicon, growth of 3-D silicon nanostructures, deuterium processing and hot electron degradation in semiconductor devices, atomically precise dopant mapping, cross-sectional STM of semiconductor heterostructures, oxide silicon interface mapping, carbon nanotube purification

Yi Ma
Computer vision, including multiple view geometry, structure from motion, dynamic vision, real-time tracking, and active vision; systems theory, including geometric nonlinear control, hybrid systems, vision-based robotic control and navigation

Juraj V. Medanic
Systems theory, control systems, systems analysis

Sean Meyn
Optimal control, Markov processes (with or without control), stochastic approximation and adaptive control, reinforcement learning and simulation, spectral theory and large deviations, information theory, stochastic networks

Pierre Moulin
Image and video processing, compression, statistical signal processing, information hiding, information theory

Klara Nahrstedt
Quality-of-Service (QoS) management, integration of guaranteed and best effort services for audio/video/DATA traffic, QoS-aware resource management, QoS routing, multimedia security, soft real-time scheduling, middleware support for distributed multimedia applications

Natasha Neogi
Aerospace software, hazard elimination using backwards reachability techniques in discrete and hybrid models

David Nicol
Cyber-security, modeling and analysis of computer and communications systems, high performance simulation, parallel processing
William D. O'Brien, Jr.
Ultrasonic biophysics and bioeffects, acoustic microscopy, ultrasonic bioengineering, ultrasonic dosimetry, ultrasonic tissue characterization, acoustic imaging techniques

Sanjay Patel
Computer architecture, microarchitecture, high-performance and reliable computer systems, the implications of future generation applications and implementation technologies on systems design

Janak H. Patel
VLSI testing and testability, VLSI design automation

William R. Perkins
Control systems, system theory, sensitivity theory and robust control, large-scale dynamic systems

Constantine D. Polychronopoulos
Parallelizing/optimizing compilers for multithreaded architectures, program restructuring and optimization; code generation and optimization for superscalar processors; parallel programming languages; environments for parallel programming; partitioning, scheduling, and run-time environments for parallel computers; multiprocessor operating systems with multithreading support; parallel computer architectures; performance evaluation of parallel architectures

Umberto Ravaioli
Monte Carlo simulation of high speed electronic devices; numerical methods for semiconductor device simulation; quantum devices; supercomputing and visualization; reliability of MOS devices; micro- and nano-electromechanical systems (MEMS and NEMS); charge transport in biological systems (ionic channels); properties of carbon nanotubes

Angus A. Rockett
IV, III–V, and chalcogenide semiconductors, materials for solar cells, theory of crystal growth, defects in semiconductors, contact metallurgies, solid phase reaction kinetics, surface science, microelectromechanical systems

Elyse Rosenbaum
Design of ESD-protected RFICs, modeling and simulation of ESD protection circuits, silicon-on-insulator, design of very high speed I/Os, gate oxide reliability

William Sanders
Dependability, security, and performance evaluation; intrusion- and fault-tolerant systems; reliable and secure distributed systems

Dilip V. Sarwate
Communications, coding theory, spread-spectrum communications, design of algorithms

Peter W. Sauer
Electric machinery modeling, analysis and control, power system dynamic modeling and simulation, power system stability

Lui Sha
Distributed real-time computing systems, dynamic real-time architecture, Quality-of-Service (QoS) driven resource management, security and fault tolerance in networked embedded systems

Naresh Shanbhag
Design and VLSI implementation of low-power, high-performance multimedia digital signal processing and communications systems, noise-tolerant deep submicron VLSI systems, fundamental bounds on efficiency of VLSI information processing systems, power-aware reconfigurable DSP systems, low-power DSP and circuits, DSP and communication system design, digital ASIC design

Yoshihisa Shinagawa
Computer graphics, vision, and its applications

Andrew Singer
Statistical signal processing, communications, machine learning, data compression, sonar/lidar/optical signal processing

Mark W. Spong
Nonlinear control theory, robotics, mechatronics, networked control systems, teleoperation, bipedal locomotion

R. S. Sreenivas
Discrete-event systems, automatic control simulation

Rayadurgam Srikant
Internet, wireless networks, sensor networks, game theory, queueing theory, information theory

Gary Swenson
Remote sensing of the atmosphere from ground-based, aircraft, and spacecraft using optical methods; space environment issues with a particular emphasis on spacecraft glows
Timothy N. Trick, Emeritus  
Computer-aided analysis and design of circuits, computer-based education

John Tucker  
Metal silicide source/drain MOS transistors at ~10nm gate length, atom-scale electron devices made by STM patterning of donors in silicon, nanoscale architectures

Nitin Vaidya  
Wireless networking, mobile computing, fault-tolerant computing

Venu Veeravalli  
Distributed wireless sensor systems, wireless packet data networks, channel modeling for wideband multiantenna wireless systems, information theory for wireless communications, wireless code division multiple access (CDMA) systems, radio resource management for wireless networks, decentralized dynamic decision making, sequential multihypothesis testing and change-point detection

Pramod Viswanath  
Communication theory, wireless communication, information theory, communication networks

Petros G. Voulgaris  
Robust control of time-varying and nonlinear systems, general systems theory, estimation and identification of complex systems, emphases on aerospace applications

Benjamin W. Wah  
Nonlinear optimization, parallel processing, distributed processing, artificial intelligence, computer networks, multimedia signal processing

Martin Wong  
Computer-aided design of VLSI, design for manufacturing, routing for high-speed packaging, field-programmable systems, design and analysis of algorithms, combinatorial optimization

Advanced Automation

Automated Visual Learning of Safety Appliances on Railcars  
N. Ahuja,* C. Barkan,* J. M. Hart, C. B. Liu  
nahuja@uiuc.edu  
American Association for Railroads

This project is aimed at the development of visual learning techniques and their implementation for automatic checking of the state of safety appliances on a moving train. This consists of the following stages: acquisition of images of railcars for inspection of the safety appliances located on the railcar sides; identification of image characteristics associated with the health of the safety appliances; identification of types of models useful to represent the railcar appearance when the safety appliances are in satisfactory condition, and if necessary, to represent unsatisfactory condition as well; application of models to learn the descriptions of safe and unsafe appliances; and application of the results of learning to railcar classification.

Globally Coordinated Locally Linear Models  
N. Ahuja,* H. Arora, A. Briassouli  
nahuja@uiuc.edu  
Office of Naval Research

This project is aimed at modeling spatiotemporal variations in video sequences such as variations in raw color values, as well as certain functions computed on these values. Since an arbitrary scene consists of distinct objects occupying different parts at different times, making video sequences nonstationary, the goal is local rather than global spatiotemporal modeling. The applicability of the models being developed extends beyond video, to a variety of multivariate, multidimensional data encountered in everyday life.

Machine-Vision Based Assessment of Intermodal Railroad Loading Patterns  
N. Ahuja,* C. Barkan,* J. M. Hart, S. Todorovic, P. Vemuru  
nahuja@uiuc.edu  
Burlington Northern Santa Fe

This project is the design and implementation of a computer vision system for automatic assessment of the loading pattern of trains passing by a wayside monitoring station. The research is concerned with the following major areas: development of algorithms for automatic inspection of double stack railcars, identification of advanced imaging sensors to enhance algorithm performance, field testing of

* Denotes principal investigator.
the algorithms and sensors, and the development of a field deployable wayside system to demonstrate a proof of concept. The system needs to have the following capabilities: to image parts of a moving train, to identify specific double stack cards in the train, to analyze key portions of these images to detect the presence or absence of loaded containers, and to detect occurrences of double stack loading.

**Next-Generation RFID Systems: People and Object Tracking for Homeland Security Applications**

N. Ahuja,* J. Bernard, * G. Horn, R. Jaehne,* V. Kindratenko,* S. Patel,* N. Vaidya,* T. Yu, B. Ghanem
n-ahuja@uiuc.edu
University of Illinois

This project is aimed at developing methods for tracking and localization of people in buildings. A central feature of the proposed work is the use of Radio Frequency Identification (RFID) tags. Current RFID technology has inadequate reliability, particularly for homeland security applications. The goal of this project is to pursue research on next-generation RFID systems, in collaboration with application domain experts at the Illinois Fire Service Institute, e.g., to help firefighters and other first responders do their jobs more effectively.

**Recognition and Contents-Based Retrieval of Hand Gestures from Video**

N. Ahuja,* A. Briassouli, A. Sehgal
n-ahuja@uiuc.edu
U.S. Office of Naval Research, N00014-03-1-0107

This project is concerned with recognition of scenes from the spatiotemporal structure of the video data. Trajectories of scene contents seen in the video sequence are used as the basis for this purpose. Objects are characterized by their spectral properties as well as temporal behavior. Such representations are used for information access as well as for recognition using such methods as support vector machines.

**Scale Dependent Processing of Clustered Sensory Signals**

N. Ahuja,* A. Feng,* M. Nelson,* C. Gao, H. Arora
n-ahuja@uiuc.edu
National Science Foundation, NSF IBN 04-22073

The broad objective of this proposal is to understand the computational algorithms used by animals to extract individual signals that are embedded in a cluster of similar signals. Our major hypotheses are: that characteristics of the received signal and the separability of individual components will vary as a function of distance from the cluster; that computational algorithms for detection, localization, and identification should reflect these scale-dependent changes; and that motor strategies and sensory filtering properties should be adaptively adjusted when processing sensory signals at different distance scales.

**Advanced Processing and Circuits**

**AlGan/GaN HFET Fabrication and Characterization**

I. Adesida,* V. Kumar, A. Kuliev
Triquint Corporation
Conducted in the Micro and Nanotechnology Laboratory

This project involves a collaboration with Triquint Corporation on the fabrication of AlGan/GaN HFETs. Technologies for the fabrication of the HFETs will be developed.

**Gallium Nitride Optoelectronics**

I. Adesida,* L. Zhou
Conducted in the Micro and Nanotechnology Laboratory

This project focuses on experimental issues for the fabrication of novel optoelectronic devices and circuits in gallium nitride and related materials. UV detectors, field effect transistors, and heterojunction bipolar transistors will be investigated. Methods for integrating these devices will also be explored.

**Porous GaN: Production, Characterization, and Applications**

I. Adesida,* P. Bohn,* X. Li,* S. Kim
U.S. Office of Naval Research, N00014-01-1
Conducted in the Micro and Nanotechnology Laboratory

This program involves the generation and characterization of porous GaN and SiC for applications in growth of high quality epitaxial layers. Matrices with dimensions down to 50 nm are to be achieved for the porous materials.

**Processing of Gallium Nitride and Related Compounds**

I. Adesida,* L. Zhou, F. Khan
ATMI/Air Force
Conducted in the Micro and Nanotechnology Laboratory

This program consists of the development of viable processing methods for gallium nitride and related compounds. A systematic study of etching techniques, ohmic contact formation, and other metallizations will be conducted and applied to devices.

* Denotes principal investigator.
Resonant Enhanced Modulators
I. Adesida,* S. Rommel
Air Force; Sarnoff Corporation

Conducted in the Micro and Nanotechnology Laboratory

This is a collaborative program with Sarnoff Corporation on resonant enhanced modulators in InP-based heterostructures. Waveguides with coupling rings are to be fabricated and characterized in InP-heterostructures. High precision patterning using inductively coupled plasma reactive ion etching and electron beam lithography will be used in fabricating the modulators.

Silicon-Germanium Modulation-doped Field Effect Transistors
I. Adesida,* K. Ismail*
National Science Foundation, ECS 97-10418

Conducted in the Micro and Nanotechnology Laboratory

This collaborative program with IBM Corp. is intended to significantly advance the growth and fabrication technologies for SiGe/Si modulation-doped field effect transistors (MODFETs) needed for low-power, high-speed microwave and digital applications. Specific goals are to study the physics of short gate-length p-type, n-type, and complementary MODFETs and to demonstrate simple circuits.

Ultra-High-Power GaN Power Amplifier at X-Band
I. Adesida,* W. Lu, D. Selvanathan
Air Force; TRW Corporation

Conducted in the Micro and Nanotechnology Laboratory

This collaborative project with TRW Corporation is to fabricate an ultra-high-power GaN-based HFET amplifier on SiC at X-Band. Various processing techniques for GaN will be developed as part of this project.

Aeronomy

Engineering Services and Utilities for ST Radar Operation at the Sidney Field Station
E. Kudeki,* S. Henson
National Science Foundation; SBC Utah State University

This grant concerns the operation of an ST radar at the university's Sidney Field Station. Tropospheric and stratospheric wind, reflectivity, and aspect sensitivity measurements to be conducted with the Sidney radar will complement similar measurements conducted by similar radars operated at the Urbana Atmospheric Observatory and Bondville Field Station. The three-radar network will be used in correlative studies of atmospheric gravity wave propagation in the troposphere and the lower stratosphere as well as phenomena associated with the evolution and dynamics of weather fronts.

Engineering Services and Utilities for the Bondville Field Station
E. Kudeki,* S. Henson
National Oceanic and Atmospheric Administration, 52 RANR 100075

Continuous operation of the FLATLAND ST (stratosphere-mesosphere) radar administered by NOAA is maintained at the Bondville Field Station. The FLATLAND radar, operating at a frequency of 50 MHz, has been designed to investigate the dynamics of the atmosphere above a plain area with insignificant orographical forcing. The routinely measured reflectivity profiles and Doppler spectra are collected in a NOAA database. Joint measurements with the Urbana Field Station MST radar are performed to investigate the horizontal scale lengths of atmospheric gravity waves and to follow the transit of weather fronts.

Radar Studies of the Equatorial Ionosphere
E. Kudeki,* E. Chapin, S. Bhattacharyya, J. Urbina
National Science Foundation, ATM 90-22400

The 50 MHz Jicamarca Radio Observatory located near Lima, Peru, is used to investigate the structure and dynamics of the equatorial ionosphere. In the mesosphere ionospheric D region, investigations aim to resolve the internal structure of narrow echoing layers and determine the relevant scattering/reflection mechanisms. In the higher ionosphere, E- and F-region plasma drifts, instabilities, and turbulence are under study. Current projects include efforts to quantify the anisotropies of equatorial plasma turbulence, obtain interferometric images of plasma irregularity structures, and measure the component of ionospheric drifts in the geomagnetic field direction. Major research effort is dedicated to the refinement of radar techniques suitable for these studies.

Applied Computation Theory

Ethical Implications of Biases and Errors in Geographic Information Systems
M. C. Loui,* C Graeff
University of Illinois

Geographical information systems combine traditional maps with additional data. The design and use of a geographic information system (GIS) can introduce a

* Denotes principal investigator.
variety of biases and errors. We identified and classified biases and errors in GIS data that arise inevitably from limits on the accuracy of gathered data, from limits on the precision of measuring instruments and display technologies, and from the combination of data in incompatible formats from multiple sources. We explained how designers and users of a GIS can work with these inherent biases and errors in a professionally responsible way.

National Institute for Engineering Ethics Video Project: A Sequel to Gilbane Gold
National Science Foundation, SES-0138309

We have developed a new video, "Incident at Morales," to dramatize a fictional but realistic case study in engineering ethics. The new video is directed to a broad audience, including engineering students, practicing engineers, and others who work with engineers. It focuses on ethical aspects of engineering decisions. Because of the globalization of the economy, the new video shows a case in an international context. We are assessing the pedagogical effectiveness of the video.

Studies in Algorithms and Complexity Theory
M. Loui,* E. Echevarria, S. Pae, M. Roman, M. Rosulek
University of Illinois

We studied the optimal generation of random numbers using a discrete random source. When the source distribution is unknown, we characterized the optimal functions and showed that they can be computed efficiently. When the source distribution is unknown, we proved that it is impossible to construct an optimal tree algorithm recursively, using a model based on algebraic decision trees. We proved that no circuit family can approximate the permanent function unless the polynomial hierarchy collapses. We constructed a set that splits every NP-complete set into subsets that cannot be reduced to each other unless P = NP.

Student Misconceptions in an Introductory Digital Logic Design Course
C. Zilles,* J. Longino, M. Loui
University of Illinois

Conducted in the Coordinated Science Laboratory and in the Department of Computer Science

We are developing a concept inventory in digital logic design. We interviewed students who had taken an introductory digital logic course to determine common student misconceptions. Based on the interviews, we developed and administered a prototype assessment tool.

Automotive Systems

Integrated Vehicle Dynamics
A. G. Alleyne*
University of Illinois at Urbana-Champaign; Ford Motor Co.
Conducted in the Mechanical Engineering Building

Presently, components of the vehicle act independently of one another to control various aspects of the vehicle's dynamics. In this research, the dynamics of a moving vehicle are controlled by coordinating and integrating the various subsystems of the chassis. Wheel torque, steering forces, and suspension forces are combined in a synergistic approach to achieve levels of vehicle performance and safety that are superior to previous approaches. Extensive use of modern control techniques is made to determine the optimal combination of forces.

Bioacoustics

Development of Intelligent Hearing Aid
A. Feng* (Physiol.); D. L. Jones, B. C. Wheeler, W. D. O'Brien; C. Lansing, R. Bilger (Speech & Hearing)
Phonak, Inc.
Conducted in the Beckman Institute for Advanced Science and Technology

This project aims to refine binaural signal processing algorithms for hearing aids so that they are suitable for real-time implementation in a commercial hearing aid. Also studied is wireless communication between hearing aids and support devices located on the body.

Advanced Hearing Protection
W. D. O'Brien, Jr.,* C. R. Lansing, Y. Liu, X. Yin
wdo@uiuc.edu
U.S. Air Force Office of Scientific Research, F49620-03-1-0188
Conducted in the Beckman Institute for Advanced Science and Technology

The objective is to develop an understanding, based on first principles, of the reception and conduction paths of very-high-amplitude air-borne sound levels (about 150 dB) to the inner ear by soft and hard tissues in order to design an advanced hearing protector device. The computational

* Denotes principal investigator.
goal is to develop an acoustic propagation model using well understood and documented computational techniques that will model propagated acoustic signals around and inside the human head. Modeling of acoustic diffraction around stationary and moving complex geometries will be accomplished with finite-element analysis (FEA). This model will take into consideration the effects of diffraction of sound around the human head and the direction from which the sound has traveled from the acoustic source to the human head.

**Evaluation of Inertial Cavitation's Role in Sonoporation**

W. D. O'Brien, Jr.,* J. F. Zachary* (Pathobiol.), M. M. Forbes (Bioengr.)

*Internal Funds*

The objective of this interdisciplinary research project is to examine and characterize how the interaction of a contrast agent with ultrasound alters the cell membrane to large molecules. A significant problem in cancer therapy is the compromised quality of life experienced by the patient due to the side effects of the therapeutic compounds. Delivery of molecular medicine to solid tumors is often inefficient and as a result, the patient’s healthy cells and tissues are subject to the toxic effects of the drugs. Thus, it is important to develop approaches that deliver drugs to the appropriate cells within the patient in a way that is specific, efficient, and safe. One such method involves the use of ultrasound to enhance cell permeabilization. With this method it is possible, by using ultrasound and contrast microbubbles, to deliver therapeutic compounds noninvasively into specific target cells.

**In Vivo Ultrasonic Microprobe for Tumor Diagnosis**


*National Institutes of Health, National Cancer Institute, CA079179*

*Conducted in the Beckman Institute for Advanced Science and Technology*

The objective of this interdisciplinary research program is to develop the basis for a fundamentally new sensor technology for an in situ evaluation of solid tumors with the expectation of rapid and accurate detection and diagnosis of cancer. The specific goal is to develop an in vivo ultrasonic microprobe sensor that operates at ultrasound frequencies up to 300 MHz and image resolution to 5 micrometers. With these sensor and imaging capabilities, research is scheduled to assess differences in acoustic cytoarchitectural features of normal tissues from neoplastic tissues at the cellular level.

**Inertial Cavitation and Neovascularization**


*Beckman Institute for Advanced Science and Technology*

The objective of this interdisciplinary research project is to examine and characterize how the interaction of a contrast agent with ultrasound alters the expression of vascular growth factor molecules following capillary injury. The generation of these data will allow for a more clear understanding of the safety issues surrounding the use of ultrasound contrast agents to assess blood flow and myocardial perfusion in human patients. Microbubble ultrasound contrast agents are valuable diagnostic tools for physicians, but their use must be considered in the context of risk-benefit assessment for each patient. The medical significance of and long-term potential benefits from the use of ultrasound contrast agents are clear; however, concerns related to their “safe use” have been raised because of reports of microbubble ultrasound contrast agent-induced vascular injury. Currently, the medical significance and pathogenesis of such phenomena are not clearly understood. Because ultrasound contrast agents are poised to be used to assess myocardial and skeletal muscle perfusion, the results of our study are an early step in developing an understanding of the primary bioeffects (injury) of ultrasound contrast agent on capillary beds of the heart and circulatory system.

**Novel Methods for Aberration Correction in Medical Ultrasound**

W. D. O'Brien, Jr.,* D. L. Jones,* M. A. Haun

*University of Illinois Research Board*

*Conducted in the Beckman Institute for Advanced Science and Technology*

The objective is to develop aberration correction techniques for medical ultrasound that will allow imaging through any type of biological tissue, in the presence of large variations in the sound propagation speed. One example of this would be ultrasound imaging and surgery in the brain, which is impossible today because of skull-induced distortion. The interdisciplinary project incorporates expertise in the areas of medical ultrasound and signal processing. The project’s purpose is to conduct the preliminary studies of a new ultrasonic imaging capability that would yield a significant improvement in spatial resolution, an improvement that could be as much as a factor of 10 better than what is currently achievable. If this were accomplished, the diagnostic capability of

* Denotes principal investigator.
medical ultrasound would experience a significant improvement.

**Temperature Estimates During Diagnostic Ultrasound Exposures**

W. D. O'Brien, Jr.,* J. F. Zachary (Pathobiol.), T. A. Bigelow

* Beckman Institute Research Assistantship to T. A. Bigelow

Conducted in the Beckman Institute for Advanced Science and Technology

The goal is to develop a quantitative assessment of tissue temperature increase under *in vivo* and *in utero* ultrasound exposure conditions, thereby providing the capability for the medical professional to know the temperature increase, and hence the risk of the desired diagnostic exposure. Of particular importance is the heating near the developing cranial bone because heating of the developing brain tissue can result in long-term neurological disorders. There is a fundamental trade-off between the improved diagnostic capability and the resulting increased risk. The risk from a diagnostic ultrasound procedure is well understood by medical professionals provided that the risk can be appropriately identified and quantified.

**Ultrasound Contrast Agents; Dynamic Physical Behavior and Bioeffects**

W. D. O'Brien, Jr.,* P. Laugier* (Université Pierre et Marie Curie, UMR C.N.R.S. 7623, Paris)

* University of Illinois-Centre National de Las Recherche Scientifique Collaborative Research Program

Conducted in the Beckman Institute for Advanced Science and Technology

The objective of the program is to develop a collaborative interaction between the two research groups that will investigate the physical interaction mechanisms between ultrasound and contrast agents. The two research programs are the Bioacoustics Research Laboratory, Department of Electrical and Computer Engineering, University of Illinois and Laboratoire d'Imagerie Paramétrique, Université Pierre et Marie Curie–Paris 6, Paris, France. Both research programs have contributed significantly to the capabilities of diagnostic imaging. During the last decade, ultrasonic contrast agents have provided clinical ultrasonic imaging with a new and powerful capability to image structures not previously possible. These agents are made of small microbubbles (< 5 µm in diameter) that are administered into the vascular system of the body to enhance ultrasound image contrast. Ultrasound contrast agents are used as adjuncts in routine ultrasound evaluations to enhance sonographic contrast and thus increase the opportunity for early detection, diagnosis, and treatment of a variety of disease processes including heart disease and cancer. Concerns about the potential bioeffects of inertial cavitation associated with the interaction of ultrasound with contrast agents in human beings have been reported. The center topic involved in this cooperative program between the two research programs is the connection between bioeffects and the bubbles responses to ultrasonic insonification.

**Ultrasound-Induced Lung Damage Assessment**

W. D. O'Brien, Jr.,* L. A. Frizzell; J. F. Zachary* (Pathobiol.), D. G. Simpson (Statistics), R. J. Miller, J. P. Blue

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National Institutes of Health, National Heart, Lung and Blood Institute, HL58218

Conducted in the Beckman Institute for Advanced Science and Technology

The objective of this interdisciplinary research program is to evaluate a significant ultrasound-induced biological effect of lung tissue. It is known that diagnostic ultrasound exposure conditions can produce damage to lung tissue in a limited number of animal species. Thus, the emphasis of the program is to conduct both experimental and theoretical evaluations in order to develop a fundamental understanding of the mechanisms responsible for producing lung damage and from this understanding provide a best-case extrapolation to the likelihood of similar damage in humans.

**Tumor Diagnosis through Enhanced Ultrasound Imaging**


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National Institutes of Health, National Cancer Institute, F32CA96419

Conducted in the Beckman Institute for Advanced Science and Technology

The objective is to develop and refine a fundamentally new approach to enhance ultrasound imaging of biological tissues by the quantification of tissue microstructure through acoustic backscatter. This enhanced imaging technique will then be adapted for real-time *in situ* clinical diagnosis of solid tumors with the expectation of producing acoustic images that will provide an accurate diagnosis of cancer. Use of enhanced ultrasound imaging is medically

* Denotes principal investigator.
significant because it offers a quick and noninvasive means of detecting and classifying tumor types.

**Novel 3-D Histologic Methodology to Identify Ultrasound Scattering Sites in Tissue**

J. F. Zachary* (Pathobiol.), W. D. O’Brien, Jr.*, J. Mamou, M. L. Oelze

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The objective of this interdisciplinary research project is to quantify microscopic tissue structures responsible for ultrasound scattering. It is, in part, these microscopic tissue structures that pathologists use to diagnose disease. Our hypothesis is that tissue microstructure (e.g., size, shape, concentration, and ultrasonic properties) of pathologic tissue (e.g., solid tumors) is measurably different from that of the surrounding healthy tissues, thus providing image contrast. The approach is to construct 3-D microscopic tissue models from normal and pathologic tissues, and from these computational phantoms, compare the theoretical ultrasound scattering from 3-D acoustic impedance maps with experimental scattering results.

**Biomaterials**

**Development of Nanoliter Calorimetry for Biomaterials**

L. H. Allen,* T. Siaf, M. Wheeler

*National Science Foundation, ECS 0304149

Miniaturized measurement instruments have been developed in the field of MEMS. Their use in biological studies will add a whole new dimension for investigations in microbiology and protein research. The goal of this project is to measure processes in biology, such as those for protein folding and for ultrasmall volumes on short time scales, with a new technique made possible via MEMS membrane technology. Our group has developed the most sensitive scanning calorimetry device to date for materials characterization in metals and polymers—nanocalorimetry.

**Circuits**

**An Integrated Design Methodology for Low-Power DSP and Communications Systems**

I. N. Hajj,* N. R. Shanbhag,* S. Bobba

*National Science Foundation, MIP-9710235

The goal of this project is to develop an integrated computer-aided design (CAD) approach for the design of low-power hardware for digital signal processing (DSP) and communications applications. The approach incorporates high-level (algorithmic) and low-level (circuit) parameters and includes novel capabilities for design exploration and low-power circuit synthesis. The design exploration will be done by developing low-power constrained algorithm design procedures that employ an analytic relation between word-level and bit-level signal statistics. The synthesis effort will incorporate signal statistics, high-level hardware models, and algorithm transformations to generate low-power dedicated implementation of DSP algorithms.

**Full-Chip Simulation of Charged Device Model ESD**

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*UMC

The capability to perform circuit simulation of ESD events increases the number of parts that pass ESD Qualification on the first try. The charged device model (CDM) best represents yield reducing events that occur in modern factories. The CDM represents the single pin discharge of a packaged chip that is at a potential hundreds of volts above ground. We are investigating whether sufficiently accurate CDM simulation results can be obtained using only a small simulation netlist that contains macro-models of the multiple discharge paths. The various power domains are linked through the substrate, and an appropriate model of it must be developed.

**Highly Reliable Receiver Circuits for High-Speed IO Links**

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We are applying communication theory to design ESD-protected, high-speed serial links. Links are expected to provide data rates in excess of 10 Gb/s at a BER less than $10^{-15}$, per-channel power consumption less than 100 mW, and a 3-KV HBM-ESD protection level.

* Denotes principal investigator.
Algorithms and VLSI Architectures for Joint Equalization and Decoding
N. R. Shanbhag,* A. C. Singer, S. J. Lee
CCR-9979381; CCR-00-85929

This project explores efficient algorithms and architectures for joint equalization and decoding in high data-rate communications systems. Such systems suffer from intersymbol interference (ISI) and noise. Conventional approaches separate the two functions of equalization and decoding for historical reasons. Significant improvements in bit-error rates are feasible if the two functions are executed jointly. Techniques such as turbo equalization are being explored where the equalizer and the decoder exchange soft information to enhance performance. Application of these new receiver techniques to broadband communication systems such as very high-speed digital subscriber lines (VDSL) and wireless is being studied.

Fluid IP Core Generators
N. R. Shanbhag, B. Lam, M. Zhang, B. Shim
Defense Advanced Research Projects Agency

This project seeks to develop design techniques and tools for realizing custom-quality VLSI designs in synthesis quality design cycle times for DOD applications. The focus of our research is on datapath intensive broadband communication subsystems, such as filters and FFT. The design methodology includes an architecture optimizer and a layout synthesizer bypassing logic synthesis. Techniques such as device sizing, noise-tolerance (both at the circuit and algorithmic level), algorithm transforms, power, and delay models are being incorporated into the core generator. The resulting circuit layouts are targeted to meet power, delay, and reliability specifications.

High-Speed Architectures for Iterative Decoders
N. R. Shanbhag,* M. Mansour
CCR-9979381; CCR-0085929

This research focuses on the design of high-speed iterative decoders. Recently, turbo codes, low-density parity check (LDPC) codes, and related concatenated codes have been proven to be extraordinarily effective in improving the bit-error rates on noisy communication links. Decoders for such codes are iterative and block-based, making high data-rates difficult to achieve. These decoders are also memory intensive. Our research explores alternative decoding algorithms that might be appropriate for low-power and high-performance VLSI implementations.

High-Speed IO Signaling
N. R. Shanbhag,* G. Balamurugan, H. M. Bae, S. Sridhara
Intel

The goal of this project is to investigate solutions for data transmission in the range of 5Gb/s–10Gb/s for inter-chip communications. The project involves the application of communications and signal processing theory and techniques to analyze high-speed I/O links. Until recently, design efforts have been focused primarily on transceiver electronics without comprehension of the communication channel. In addition, no rigorous, comprehensive analysis techniques exist to analyze and predict the performance of I/O signaling systems. By viewing the I/O link as a noisy communication channel over which reliable information transfer needs to take place, the project proposes to develop analysis methods and explore design possibilities to accomplish reliable energy-efficient high-speed data transfer over inter-chip links.

Noise-Tolerant DSP in the Deep Submicron Era
N. R. Shanbhag,* R. Hegde, L. Wang, G. Balamurugan
National Science Foundation, CCR-9902745

This research addresses the design of reliable and energy-efficient DSP systems in deep submicron (DSM) SMOS technology in a unified manner via the development of noise-tolerant algorithmic and circuit design techniques. In particular, circuit design techniques that tolerate leakage, crosstalk, ground bounce, and process variations are being developed. Algorithmic approaches that exploit the statistical structure of multimedia signals to combat DSM noise are also being studied. A design methodology is being formulated that jointly applies circuit and algorithmic noise-tolerance techniques to achieve an overall level of system reliability while minimizing energy.

VLSI Architectures for Soft Decoding of Reed–Solomon Codes
N. R. Shanbhag,* R. Koetter, R. Blahut, A. Ahmed
CCR-0073490

This project investigates high-performance architectures for soft decoding of Reed–Solomon codes. Reed–Solomon codes are commonly employed to enhance the reliability of broadband communications links. Reed–Solomon decoders used in practice today employ hard-decision decoding. Soft decision decoding of Reed–Solomon codes can provide significant coding gains over hard-decision decoders. Soft decision decoding algorithms are computationally complex and hard to implement in VLSI. This research explores algorithmic and architectural
techniques to design soft decision Reed–Solomon decoders for high-data rate communication systems.

**CAD for VLSI Manufacturability and Reliability**
M. D. Wong*
*National Science Foundation*

In nanometer-design technologies, computer-aided design software must consider manufacturability and reliability. In this project, we focus on the development of theories and prototype systems for solving problems in the design for manufacturability and reliability area. Research topics include lithography-aware design tools, fast reticle enhancement techniques (OPC, PSM, OAI, and such), and layout optimization for CMP.

**Routing for High-Performance VLSI Packaging**
M. D. Wong*
*IBM*

In this project, we develop a complete routing system for high-performance circuit boards. The type of high-end boards targeted in this project is generally completed using manual methods because of the complexity or density of the design. The goal is to create a system that will either completely remove the need of manual routing or significantly reduce the effort of manual routing. Such a system will dramatically reduce the design time for state-of-the-art, high-performance complex boards.

**Communications**

**Fair Scheduling and Admission Control for Shared-Channel Wireless Packet Networks**
*National Science Foundation*

Fair scheduling of traffic sources in wireless networks is difficult due to bursty channel errors and location-dependent channel capacity. In this project, researchers study MAC, scheduling and admission control algorithms for indoor and outdoor wireless networks that allocate the available bandwidth in a fair manner to competing sources.

**Codes on Graphs, Factor Graphs, and Iterative Algorithms**
R. Koetter*
*National Science Foundation Career Award, CCR 99-84515*

The primary focus of this research is the investigation of creative new methods for reliable transmission of information in the context of modern error-control techniques. Error-correcting codes are an essential part of modern communication and storage systems and much of today's technology would not be possible without them. This study is focused on graph-based, iterative decoding algorithms, which, without doubt, are one of the most significant coding-theoretic developments of the last decade. The goal of the investigator's research is to develop a broad, analytical, and constructive approach to research and education, unifying graphical models, coding theory, and iterative algorithms. The interplay between codes on graphs and other areas, like iterative graph-based algorithms, system theory, and network information theory, is in the focus of this investigation with the goal of discovering and utilizing fundamental connections between these fields.

**High-Performance Short Iterative Codes**
R. Koetter*
*Motorola, Inc.*

This project aims at developing excellent codes for application requiring short- to moderate-length (64 bits to <1,000 bits) codes. Traditional coding schemes for these lengths rely typically on algebraic constructions or convolutional codes. Researchers strive to make the tremendous gains achievable for long blocklengths (>10,000 bits) by turbo and other iteratively decodable codes available for much shorter code length.

**Unwrapping Phase Images: Theory and Applications Using Probabilistic Inference Techniques**
R. Koetter,* B. Frey, D. Munson
*National Science Foundation, CCR 01-05719*

Phase unwrapping in two-dimensional topologies is a signal processing problem that has been studied extensively over the past 20 years and has important applications, such as medical imaging and synthetic aperture radar. However, despite its importance in science and engineering, to date, phase unwrapping in two-dimensional grids has remained an essentially unsolved problem. This research takes a fresh approach to the problem using methods from probabilistic inference. The work not only holds the promise of resulting in powerful phase unwrapping schemes based on the sum-product algorithm and structured variational methods, but also has the potential to provide deep theoretical insight into the ill-posed nature and solvability of the phase unwrapping problem. Such an insight is extremely important for guiding the development of practical algorithms.

* Denotes principal investigator.
Design Principles for Wideband Wireless Communications
V. V. Veeravalli,* A. Mantravadi
Cornell University, NSF CCR-9980616

This research is aimed at enhancing the performance of wideband wireless multi-access systems by optimizing tradeoffs between coding and spreading, capitalizing on advantages afforded by spatial diversity, and developing techniques for accommodating multirate users.

New Techniques for Optimizing the Quality and Capacity of Wireless Communication Systems
V. V. Veeravalli,* J. F. Chamberland, Y. Liang, N. Wang
National Science Foundation, Faculty Early Career Development, Presidential Early Career Award for Scientists and Engineers, CCR-0049089

The research in this project is directed toward the development of future generation multimedia wireless communication systems. Specifically, the research spans the following four areas: wireless channel modeling and analysis; information theory for wireless systems; wireless CDMA systems; and dynamic radio resource management.

Research at the Frontier of the Physical Layer
V. V. Veeravalli,* R. Prakash, K. C. Reddy
National Science Foundation, CCR-0049085

The research conducted under this grant has a broad perspective from the viewpoint of the physical medium in that it covers wireline (twisted pair or a coaxial cable); wireless (satellite, cellular/PCS, or wireless local area network, WLAN); and recording, (magnetic or optical disc) media. The research has a narrow focus in that the problems addressed all involve some form of forward error control (FEC). A major component of the project is on coding and information theory for wireless CDMA systems.

Communications Networks

ITR: Diagnosis and Assessment of Faults, Misbehaviors, and Threats in Distributed Systems and Networks
C. Hadjicostis,* R. S. Sreenivas, K. Thulasiraman, C. Beck
National Science Foundation

The proposed research develops theory and techniques for monitoring and diagnosing faults, hazards, or more generally, functional changes in dynamic systems and networks, under limited and possibly corrupted information. We present a unifying and multifaceted approach to this problem that decomposes the large body of fault diagnosis research into six topics: deterministic fault diagnosis, model-based probabilistic diagnosis, adaptive and sequential diagnosis, distributed system-level diagnosis with communication constraints in wired/wireless networks, fault diagnosis via distributed belief propagation algorithms, and model-independent diagnosis. The research involves a synergy of several areas, including fault diagnosis, sequential detection, system-level diagnosis, distributed control, modeling, analysis and performance evaluation, applied probability, graph theory, belief propagation and model reduction to the problem of detecting, and identifying and localizing faults and abnormalities in dynamically evolving environments.

Computer Architecture and Compilers

Compiler Optimizations for Multilevel Memory Hierarchies
V. Adve,* Q. Yi (Rice Univ.), K. Kennedy (Rice Univ.)
U.S. Department of Energy ASCI Academic Strategic Alliances Program, B347884

Conducted in the Digital Computer Laboratory

Managing performance on deep memory hierarchies is widely considered to be a critical open problem for high-performance systems. This research team is exploring a novel class of compiler transformations that provide improved locality at multiple levels of memory hierarchy simultaneously. The transformations exploit the property that recursive algorithms have identical reuse patterns at each level of recursion, providing a hierarchy of working sets. Researchers are developing compiler algorithms to transform existing loop-based codes into efficient recursive form automatically. Such a transformation has wide applicability, including automatic blocking for multiple levels of cache hierarchy and improving communication locality in shared memory codes.

Compiler Support for Performance Modeling of Parallel and Distributed Programs
V. Adve*
Defense Advanced Research Projects Agency, N66001-97-C-8533

Conducted in the Digital Computer Laboratory

Researchers are developing compiler techniques that enable fast, accurate, and automatic performance modeling of highly scalable applications. One focus of this effort is a compiler-generated program representation that allows

* Denotes principal investigator.
one to automate a wide range of analytical, simulation, and hybrid models of parallel programs. A second focus is to use additional compiler analysis, together with this representation, to enable efficient simulation of highly scalable applications. One such compiler technique achieved 10-2000x reduction in memory usage and 2-10x reduction in simulation time for the simulation of large message-passing programs. This work is part of a broader collaboration with five other universities.

**Cooperative Hardware/Software Designs for Virtual Instruction Set Computers**

V. Adve,* C. Zilles,* S. Patel, P. Salverda, A. Lenharth
National Science Foundation, CCF 04-29561,
EIA-02-24453; AMD Corp.

In this work we are exploring a class of cooperative compiler/microarchitecture techniques that can improve performance and reduce the complexity and power-consumption of general-purpose processors. The key feature of these techniques is that they exploit a wide, implementation-specific instruction set interface between the compiler and the processor, enabled by the use of a virtual instruction set computer (VISC) architecture. A VISC architecture is characterized by having two instructions sets—one that is exposed to software (the virtual ISA) and another that is actually implemented by hardware (the implementation ISA)—and a translator that is used to transparently emulate the first with the second.


S. Adve,* A. F. Harris, C. J. Hughes, D. L. Jones, R. H. Kravets, K. Nahrstedt, D. G. Sachs, V. Vardhan, W. Yuan
AMD Corp.; National Science Foundation,
CCR-02-05638, EIA-02-24453

Conducted in the Digital Computer Laboratory

Mobile devices that primarily process multimedia data are expected to become a dominant computing platform for a variety of application domains. Their design must consider demanding, dynamic, and multiple resource constraints, with energy as a first-class resource. However, the ability of multimedia applications to trade off output quality for system resources offers an opportunity for the design of systems where each system layer can adapt in response to resource or application changes. Reaping the full benefits of a system with multiple adaptive layers, however, requires a careful coordination of those adaptations. This project is developing a cross-layer adaptive system and framework to reduce energy consumption while preserving application quality within available computation and bandwidth resources. The final system prototype will integrate adaptations in the hardware, network, operating system, and application layers, opening up sources of energy savings not possible before.

**Safe LLVA: Compiler Techniques for Operating System Security and Reliability**

V. Adve,* A. Lenharth,* J. Criswell, D. Dhurjati
National Science Foundation, EIA-00-93426,
CNS-04-06351, CCF-04-29561; DARPA/MARCO Gissascale Systems Research Center (GSRC)

Despite major developments in technologies for system security and reliability, today's operating systems and user processes remain vulnerable to an extensive range of attacks. At the root cause of such vulnerabilities is an important class of bugs: implementation errors, e.g., memory access errors or missing security checks. These are not addressed even by powerful, security-conscious design approaches like security kernels or virtual machine monitors. Moreover, design weaknesses in legacy kernels can magnify the potential risk when a successful exploit occurs, e.g., allowing device drivers or other kernel extensions to operate with full privilege within the kernel address space. This project is developing a compiler-based virtual machine (Safe LLVA) that is capable of hosting a standard C/C++-based operating system and all its applications, and exploring how this organization can improve overall system security and provide new security capabilities. Such a virtual machine can apply a range of compiler-based safety checking techniques on legacy kernel code. The immediate goal of this work is to apply compiler-based techniques for memory safety from the SAFECode project to kernel code to prevent attacks via memory access errors. More broadly, the combined system will also address techniques for reducing kernel implementation errors, improving application security by enforcing least-privilege, and protecting critical application data from the kernel even if it is compromised.

**SAFECode: A Compiler System for Enforcing Memory Safety in C Programs**

V. Adve,* D. Dhurjati, S. Kowshik
National Science Foundation, EIA-00-93426,
CCR-02-09202, and CNS-04-06351; SRC MARCO/DARPA consortium

Programming errors that lead to illegal memory accesses are a dominant source of vulnerabilities that lead to security violations in modern computer systems. Such errors can include buffer overruns, dangling pointer errors, and others. The SAFECode compiler automatically transforms programs to prevent all kinds of memory errors in

* Denotes principal investigator.
production code, through a combination of static and run-time checking. For safety techniques used in production code, the run-time checking introduces very low overheads. These low overheads are made possible by a novel approach for making hard-to-find errors harmless, without actually eliminating those errors. The compiler also ensures that a specific approach to program analysis can be made sound, despite the presence of hard-to-detect errors, enabling static checking and verification tools to give guarantees of soundness for the properties they claim to prove. SAFECode also provides additional techniques for debugging difficult-to-find errors like dangling pointers, through more expensive but complete techniques.

**Virtual Instruction Set Computers (VISC)**

V. Adve,* R. Bocchino, J. Criswell, D. Dhurjati, T. Lattner,
*National Science Foundation, EIA-00-93426, CCF 04-29561; DARPA/MARCO Gigascale Systems Research Center (GSRC)*

Virtual Instruction Set Computer (VISC) architectures define two separate instruction sets (one to serve as the representation of stored programs, and another to control the hardware), and use a hardware-specific translation layer to optimize and execute code on the hardware. This approach lends great flexibility to hardware and compiler design, enabling close cooperation between the translator and the microarchitecture on each individual chip (since each distinct processor design has its own specific translator). This is because the hardware instruction set can expose microarchitecture details to the translator and, conversely, can rely on the translator to produce code with predefined assumptions. This project is defining a novel virtual instruction set for VISC architectures called Low Level Virtual Architecture (LLVA) and a translation strategy that permits both offline and online translation or a combination thereof. The project is also exploring compiler and architecture techniques to exploit the VISC framework with the rich virtual instruction set for improved processor performance and reliability.

**The LLVM Compiler System**

*National Science Foundation, EIA-00-93426, CCR-02-09202, CNS-04-06351, CCF 04-29561; DARPA/MARCO Gigascale Systems Research Center (GSRC)*

Modern applications are increasing in size, change their behavior significantly during execution, support dynamic extensions and upgrades, and often have components written in multiple different languages. While some applications have small hot spots, others spread their execution time evenly throughout the application. In order to maximize the efficiency of all of these programs, program optimization must be performed throughout the lifetime of a program, including compile-time, link-time, install-time, run-time, and "idle-time" profile-guided optimization between runs. The LLVM compiler project provides a framework to make "lifelong" program analysis and transformation available for arbitrary software, and in a manner that is transparent to programmers. The LLVM system retains key program information in a language-independent format that can be used for lifelong compilation, and exploits this representation to provide a unique combination of capabilities. LLVM is available freely in open-source form and has attracted a large community of active users and contributors in industry, academia, and the open-source community.

**Computer Engineering**

**Ad Hoc Wireless Networks Utilizing Multirate and Power-Save Capabilities**

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*National Science Foundation, ANI 01-25859*

Wireless communication technology has gained widespread acceptance in recent years. Wireless local area networks have come into greater use, with the advent of the IEEE 802.11 standard and availability of several commercial products based on this standard. An ad hoc network can be formed by wireless, potentially mobile hosts, without requiring the use of any fixed infrastructure, such as base stations. Such networks have many applications, including home networking, personal area networking, sensor networking, search-and-rescue missions in remote areas, and other civilian as well as military operations. Modern wireless devices are often designed with the capability to transmit at different bit rates using different modulation schemes and to operate in a power-save mode to conserve energy. While such wireless devices can be built, there is not adequate research on performance of ad hoc networks utilizing such devices. This project will, therefore, attempt to answer two broad questions: How do we design wireless medium access control (MAC) protocols that exploit multirate and power-save capabilities in ad hoc networks? While there has been some work on such protocols, this project is expected to develop new techniques to utilize multirate and power-

* Denotes principal investigator.
save capabilities. What is the impact of multirate and power-save capabilities on performance on network layer and transport layer? The project will study the interaction between wireless device capabilities and upper layer performance, and develop mechanisms to improve performance of the various layers.

**Wireless Wind Tunnel: A Testbed for Experimental Evaluation of Wireless Networks**

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This project, evaluating protocols for wireless networks and developing scaling techniques for physical environments, aims at deploying an anechoic chamber for interference control, forming a testbed, referred to as the wireless wind tunnel (WWT). The uses of the testbed focus on: evaluation of wireless protocols (WP) in controlled environments, development of channel models suitable for simulation-based evaluation of WPs, and evaluation of techniques for scaling the physical environment to facilitate realistic wireless experiments. The WWT addresses some of the limitations based on computer evaluations resulting from the present insufficient understanding of channel and system models for wireless networks. These are not well understood and brute force accurate simulation of the wireless environment are at present too complex. Existing hardware testbeds suffer from one or both of the following shortcomings: experiments often cannot be repeated due to interference by other wireless devices operating in the same frequency range, and the parameters of the experiment (such as the mobility patterns of the mobiles and scatterers in the environment) are not fully controllable. This work impacts the education mission, including coursework, laboratories, and student projects. The testbed will serve as a demonstration tool. New educational opportunities will open involving experimental research providing better training and motivation. Facilities will be made available to a larger pool of researchers. Additional impact is expected on communications systems in practice.

**Construction Management**

**Evaluation of Lighting for Nighttime Highway Construction Operations**

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*Illinois Department of Transportation, ITRC-VD-H1*

**Conducted in the Newmark Civil Engineering Laboratory**

An increasing number of highway construction and repair projects throughout the United States are being performed during the off-peak nighttime hours to alleviate construction-related traffic congestion. Despite the apparent advantages of nighttime construction operations, a number of challenges are often encountered during this type of construction, including decreased visibility for both workers and motorists, causing decreased levels of safety and quality; problems in implementing quality control procedures; adverse public reactions due to construction noise during nighttime; and increase in cost for nighttime operations. In order to address these challenges, this project explores the development of innovative design criteria and lighting arrangements for nighttime highway construction operations. The objectives of this research are to develop and recommend design criteria for lighting nighttime highway construction; develop a design and optimization model for lighting nighttime construction sites; and implement a practical and mobile computing tool for lighting design that can be utilized by contractors in design and implementation and by resident engineers in the inspection of lighting conditions on site.

The developed lighting standards in this research will be adopted by the Illinois Department of Transportation (IDOT) for state specifications for lighting of nighttime highway construction operations. Furthermore, the developed lighting design tool will provide much-needed support for contractors and resident engineers in the design and implementation of practical and effective lighting arrangements for nighttime highway construction.

**Web-Based Management of Multiple Interdisciplinary and Geographically Distributed Research Projects**

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The main objective of this project is to develop a robust IT-based management system for engineering research centers to ensure the accomplishment of their research and

* Denotes principal investigator.
educational and outreach goals on time and within budget. To this end, a web-based system is being developed to enable remote and effective management of multiple interdisciplinary research projects that are located in different geographic regions.

**Automated Productivity and Progress Assessments Using Digital Close-Range Photogrammetry**

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Construction productivity and progress assessments are among the most challenging tasks of a construction project. Accurate measurements of productivity and progress play a critical role in the success of a construction project. This research project integrates digital close-range photogrammetry, computer vision, image reasoning, 3D-CADD, and computer databases to provide an automated system for measuring construction productivity and progress.

This research will impact how construction field data are processed and analyzed in the future.

**Construction Object-oriented Process Simulation**

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Simulation provides a practical means of analyzing construction processes to identify resource utilization and idleness, operation bottlenecks, productivity, and operational costs. This research uses object-oriented programming to design a network-based discrete-event simulation system for construction process modeling. All modeling elements are implemented as objects with integrated functionality of interactive computer graphics and simulation. Models are constructed through a friendly graphical user interface. Simulation is accomplished by having active objects send messages to one another. This paradigm of simulation system design can provide many advantages over traditional design, such as realistic resource tracking, precise simulation control, and linkage with other knowledge-based expert systems.

This research will impact how we manage construction projects in the future.

**Construction Site Digital Data Collection Devices**

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This project develops a hardhat-mounted device that collects multimedia information, including video and sound, for construction inspection and documentation. The device uses voice-activated control and allows construction inspectors to walk hands-free at the project site to document site conditions or problems. Narration, pictures, and videos can be taken and stored digitally into the device and can be ported later into a database that supports project control and documentation. A heads-up display is used for synchronizing the camera direction with the eyes. This device allows wireless, two-way communications where images can be transmitted to and from the host computer.

The project will lead to intelligent field automation in the future.

**Construction Time–Cost Trade-Off Decision Support**

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Construction engineers face the challenge of selecting the most effective construction methods for tasks within a project. Different methods, equipment, and crew sizes can be chosen for tasks depending upon the contract time limit and budget. Not all tasks are of equal importance in a project. Some tasks carry floats and can be delayed without impacting the project duration. Some tasks are critical because any delay on those tasks delays the project. Construction engineers may choose alternative construction methods, smaller crew sizes, and less productive equipment at lower costs while maintaining the same project duration. The purpose of this research is to develop a generic algorithm for assisting construction engineers in selecting optimal time–cost strategies to complete a project.

This new algorithm will support analyses of construction planning and controls, by lowering overall construction costs.

* Denotes principal investigator.
Sensor-Based Construction Quality Control and Monitoring
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This project investigates new applications of sensor devices (electrical, micro-electrical-mechanical, and fiber-optic) in construction quality control and monitoring. These sensors are imbedded in infrastructure components to collect data for monitoring the conditions and other properties relevant to safety and performance of a structure, such as a bridge, tunnel, or building.

The potential impacts of this research include a new and better approach to conduct construction inspections, more timely responses to repair needs, and lower costs for structure maintenance.

Control Systems

Advanced Dynamic Modeling and Control of Air Conditioning and Refrigeration Systems
A. Alleyne,* M. Keir, B. Eldredge
28 Company Consortium: Air Conditioning and Refrigeration Center; National Science Foundation

Conducted in the Mechanical Engineering Building

This project develops a dynamic simulation-modeling environment that is suitable for closed loop control of stationary and mobile a/c and refrigeration systems. The focus is on controlling quasi-steady transitions between operating states, instead of startup and shutdown transients, by modulating flow rates of both air and refrigerant. It builds upon previous models by making more extensive use of physical parameters, based on results from other research projects. The model development is supported by a parallel set of experiments conducted in a flexible test facility.

Control of Fluid Power Systems
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Conducted in the Mechanical Engineering Building

The modeling and control of fluid power systems includes electrical, mechanical, hydraulic, and pneumatic subsystems. Various types of advanced controllers are applied to these complex nonlinear systems. Applications of these systems range from automotive engine systems to earth-moving vehicles to high-speed machine tool drives.

Control of Nonlinear Systems
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Conducted in the Mechanical Engineering Building

The control of various nonlinear mechanical and electromechanical devices is studied. The techniques applied vary from standard linearization (Jacobian) to gain scheduling to nonlinear transformations (feedback linearization). The structure of the particular systems being controlled is exploited to facilitate control. The application of this is directed to the control of various mechanical systems.

Control of Systems in a Dimensionless Framework
A. G. Alleyne,* Y. Li, B. Morgan
University of Illinois Research Board; National Science Foundation

Conducted in the Mechanical Engineering Building

This project examines the benefits of using dimensionless system representations for control system design. Dimensionless system representations afford benefits for parameter identification as well as dynamic uncertainty representation. These benefits translate into better adaptive control and robust control designs. Current investigations examine engineered systems, such as vehicles, as well as individual subsystems and components.

Integrated Chassis Control for Vehicles
A. G. Alleyne
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Conducted in the Mechanical Engineering Building

Presently, components of the vehicle act independently of one another to control various aspects of the vehicle's dynamics. In this research, the dynamics of a moving vehicle are controlled by coordinating and integrating the various subsystems of the chassis. ABS braking systems, traction control systems, lateral stability control systems, 4-wheel drive (4WD), and controllable suspensions (active or semiactive) are combined in a synergistic approach to achieve higher levels of vehicle performance. The benefits of this approach are increased vehicle performance and safety.

* Denotes principal investigator.
Microscale Robotic Deposition
A. Alleyne,* P. M. Ferreira,* J. Lewis, D. Bristow, K. Barton, D. Mukhopadhyay, D. Hoelzle
National Science Foundation, DMI-0140466
Conducted in the Mechanical Engineering Building
The objective is to develop new materials systems, manufacturing systems, control, and planning algorithms required for microscale robotic deposition (m-RD) of colloidal gels. An integrated approach will be directed toward the fabrication of 3-D periodic structures (feature sizes less than 10 mm) required for emerging photonic applications. Such novel structures provide the optical analogues to semiconductor materials at length scales relevant for optical communication and computing technologies.

Nano-CEMMS Systems Integration Testbeds for the Micro- and Macroscale
A. G. Alleyne,* P. M. Ferreira, M. Tharayil, K. Barton, R. Khanapure
National Science Foundation, Nanoscale Science and Engineering Center, DMI-0328162
Conducted in the Mechanical Engineering Building
This work relates to the Center for Nanoscale Chemical-Electrical-Mechanical Manufacturing Systems (Nano-CEMMS) Center. We are developing systems integration tools and testbeds for rapidly identifying potential bottlenecks in the confluence of different core technologies associated with our nanoscale manufacturing efforts. The tangible results of this project will be the development of the earliest testbeds that are representative of the fully functional Nano-CEMMS system as it is currently envisioned. Additionally, this project will be able to provide systems-level planning and guidelines for the development of the overall research plan. The ability to provide planning input will grow throughout the project as better knowledge and understanding of the overall systems-level issues are developed.

X-by-Wireless Feedback Control of Coordinated Systems
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Conducted in the Mechanical Engineering Building
The goals of this project are twofold. First, the project will examine direct feedback control of individual systems via wireless connections. This is fundamentally different from previous and current wireless investigations whereby command sequences are communicated to the system while the actual device-level control takes place "on-board." Second, this project will investigate the coordination of multiple wireless users acting together to perform a controlled action. The separate users will be able to develop a connection and coordinated control strategy that will be transparent to users being added or removed as long as there are sufficient agents to perform the task.

Hierarchical and Reconfigurable Schemes for Distributed Control over Heterogeneous Networks
National Science Foundation, ITR 0085917
The research project deals with issues arising in controlling geographically distributed complex real-time systems over a heterogeneous communication network. It is aimed at developing the foundations of network-based control, from theory to applications. The overall objectives are the following: the design, analysis, implementation, and performance characterization of hierarchical and heterogeneous distributed control algorithms and middleware that are affected through hierarchical heterogeneous networks comprised of wired and wireless subnets; and specification and implementation of network services and support required for the development and deployment of distributed control algorithms over hierarchical heterogeneous networks.

Algorithmic and Differential Geometric Trajectory Planning
F. Bullo*
University of Illinois
Motion planning and trajectory optimization are key technological problems in the development of dexterous and autonomous machines, including robotic manipulators and autonomous vehicles. The first step is to introduce and characterize kinematically controllable systems. For these systems, the problem of planning fast, collision-free trajectories can be decoupled into the computationally simpler problems of path planning followed by time-optimal time scaling. Second, researchers present a power series approach to trajectory planning. Two-point boundary-value problems corresponding to trajectory planning are solved locally via an inverse theorem for power series representations. Investigations include both the regular and singular cases corresponding to linearly and nonlinearly controllable systems.

* Denotes principal investigator.
Cooperative Networked Control of Dynamical Peer-to-Peer Vehicle Systems  
U.S. Air Force Office of Scientific Research; Defense Advanced Research Projects, Multidisciplinary Research Programs of the University Research Initiative, F49620-02-I-0325  
The proliferation of computing and wireless communication technology has opened up tremendous possibilities for deploying large cooperative networks of smart vehicles to perform intricate and complex missions. It is evident that collaborative teams of aerial and ground vehicles can perform a plethora of highly beneficial tasks for achieving military objectives and civilian security. The major objective of our consortium is the development of a rigorous theoretical foundation, and scalable analytical tools and paradigms, so that systems can be systematically constructed and their performance formally verified. More generally, the activity of this program can be expected to have a dramatic impact on understanding and designing large-scale, robust, real-time distributed systems. Our goals are to make use of recent algorithmic developments to provide hard performance guarantees and bounds for systems performing sophisticated tasks in uncertain and dynamic physical situations.

Architectures for Secure and Robust Distributed Infrastructures  
S. Lall* (Stanford Univ.); C. Beck (Gen. Engr.); S. Boyd (Stanford Univ.); J. Doyle (California Technical Univ.); G. E. Dullerud; C. Hadjicostis (Elect. & Comput. Engr.); B. Lesieutre, M. Medard (MIT); B. Prabhakar (Stanford Univ.); R. Srikant (Gen. Engr.); C. Tomlin (Stanford Univ.); G. Verghese (MIT); V. Vladimirou; D. King  
U.S. Air Force Office of Scientific Research, F49620-01-I-0365  
The major barrier constraining the successful management and design of large-scale distributed infrastructures is the conspicuous lack of knowledge about their dynamical features and behaviors. Until very recently, analysis of systems has primarily relied on the use of nondynamical models. These traditional approaches have enjoyed considerable success while systems are run in predominately cooperative and “friendly” environments and provided that their performance boundaries are not approached. With the current proliferation of applications using and relying on such infrastructures, these infrastructures are becoming increasingly stressed, and the incentives for malicious attacks are heightening.

Layered Architectures for Complex Networked Systems  
M. W. Spong, P. R. Kumar, F. Bullo, C. Hadjicostis  
National Science Foundation, ECS-0122412  
Future embedded real-time control systems will increasingly be wireless, distributed, large-scale, and inherently hybrid, combining discrete or digital components with continuous time nonlinear dynamics. The complexity of such networked systems presents new challenges that lie at the confluence of communication, computing, and control. In this project, we investigate the design and analysis of layered control and communication architectures for treating complexity, delays, reliability, planning, and other issues. Our goal is to develop the right abstractions that are application independent and enable the convergence of sensing and actuation with communication and computing.

A Normative Theory for the Design of Discrete Event Dynamic Systems  
R. S. Sreenivas*  
National Science Foundation, CNS-0437415  
The goal of the project is to identify tractable synthesis of supervisory policies that control discrete event dynamic systems such as: air-traffic control systems; automated manufacturing systems; computer networks; integrated command, control, communication and information (C3I) systems; operations-management of multicomponent organizations with event-driven dynamics like shipyards, airports, hospitals, and so forth. Despite the myriad and diverse applications for DEDS, advances in core aspects of supervisory control of DEDS have not found application beyond academia, primarily due to the fact that synthesis procedures require complete specification of the desired behavior of the system, a difficult, if not impossible task. Even when complete specifications are available, the synthesis of the appropriate supervisory policy can be intractable. This project develops a normative theory of how DEDS should be structured so that, starting from a supervisory policy that enforces an incompletely specified behavior, progressive supervisory corrections can be applied such that the (complete) desired specification is eventually enforced. The supervisory policy advocated by this project is based on analysis of observed “desirable”
and "undesirable" states of a system. This project focuses on three areas of DEDS. First is a learning phase: the development of learning algorithms for supervisory systems where desired behavior can be easily earned/identified using examples/counter-examples. Second is a supervisory policy synthesis phase: the identification of DEDS structures where learning is tractable. A third area of DEDS is the progressive improvement phase: the development of methods for improving learned behavior that can be progressively improved with computations effort as additional information is made available.

Decision and Control

**Dynamic Team and Game Theory for Congestion Control in High-Speed Networks**
T. Basar,* R. Srikant,* D. Wiedenheft
*National Science Foundation, ANI 98-13710*

This project is related to NSF 98-13710, and involves research for undergraduate students on various aspects of communication networks, particularly in the area of congestion control.

**Objective-Oriented Model Heterogeneous Sensor Networks for Coordinated Control**
T. Basar,* T. Alpcan, C. Tang, S. Yuksel
*National Science Foundation, ECS 02-25481*

This is a multi-university research effort that focuses on a comprehensive study of large, mobile ad-hoc reconfigurable networks for coordinated control. It draws on elements from coordinated control, dynamic state estimation, ad-hoc network management, resource assignment, and fault tolerance. Its aim is to provide a formalism in which the methods of sensor networking may be integrated as part of a systematic design process focused on achieving a specific control objective. Particular topics of study at the present are robust H-infinity and risk-sensitive control and filtering in a receding horizon framework, performance-and utility-driven resource allocation in networks, and control over networks using decentralized and distributed sensor information.

**Smart Icing Systems**
T. Basar,* W. R. Perkins,* P. Voulgaris,* J. Melody, V. Sharma
*NASA Glenn Research Center, NAG3-2135*

This part of the larger interdisciplinary/interdepartmental research program addresses the identification and control research required to develop a smart icing system for aircraft. A smart icing system would sense the effect of ice accretion on the aircraft performance and handling qualities and provide information to the flight crew, operate ice protection systems, provide envelope protection, and possibly adapt the flight controls. The research conducted here involves in-flight parameter identification of aircraft flight dynamics utilizing excitation generated by only natural (and not forced) maneuvers of the aircraft and turbulence. Subsequently, this information would be fed (along with other sensor-based data) into an appropriate neural network that would, in turn, lead to an accurate detection of the level of severity of ice accretion on the flight surfaces of the aircraft. The ultimate goal of this effort is to provide both the pilot and the autopilot with needed information to improve the safety of aircraft operating in icing conditions.

**Cooperative Networked Control of Dynamical Peer-to-Peer Vehicle Systems**
G. Dullerud,* F. Bullo, E. Frazzoli, P. R. Kumar, D. Liberzon, B. Reznick, M. Viswanathan

The goal of this project is to develop systematic methodologies for the reliable construction of cooperative networked multivehicle systems.

**Architectures for Secure and Robust Distributed Infrastructures**
C. Hadjicostis,* G. Takos
*U.S. Air Force Office of Scientific Research; Department of Defense, URI Award F49620-01-1-0365URI (subcontracted from Stanford University)*

Within the context of a much larger project, this work focuses on addressing the challenges that arise in regards to distributed or hierarchical coordination, fault tolerance, safety, and scalability in emerging dynamic systems and networks. The initial goal of this project has been to develop distributed estimation algorithms that can be used in network monitoring.

**Designs of Robust Encoded Dynamic Systems**
C. N. Hadjicostis,* G. Takos
*Air Force Office of Scientific Research, DoD URI Award F49620-01-1-0365URI*

This work analyzes the effects of roundoff noise on our ability to nonconcurrently detect and identify transient faults that corrupt state variables during the operation of a fault-tolerant discrete-time LTI dynamic system. The analysis provides insights that allow us to evaluate the

* Denotes principal investigator.
performance of established decoding algorithms using analytical techniques. It also leads to explicit bounds on the precision needed in order to guarantee the correct identification of the number of faults that have affected the system.

**Enabling Diagnosis of Faults and Misbehavior in Heterogeneous Networked Systems via Structured Redundancy**

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*Boeing Corporation*

This project aims to evaluate how the use of redundant sensors, actuators or, more generally, redundant information can enable efficient and gracefully degradable diagnosis algorithms for large networked systems. Instead of focusing on how diagnosis can be performed for a given system or network, this project is interested in finding out how small modifications in the system structure (e.g., sensor or actuator allocation) or the communication links and protocols can result in more efficient and robust diagnosis algorithms.

**Error Control in Switched Linear Controllers**

C. Hadjicostis,* S. Sundaram
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*National Science Foundation, ECS 02-18939 ITR*

This project develops protection schemes for linear time-invariant (LTI) controllers in switched systems. Tolerance against internal controller faults is achieved via embeddings that preserve the state evolution of the original controller in some encoded form, but enable error detection and correction through nonconcurrent (e.g. periodic) checks.

**Operation and Control of Energy Processing Systems: Fault Tolerance Considerations**

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*National Science Foundation, ECS 02-24729 EPNES*

The main goal of this research project is to develop a comprehensive framework for dynamical state estimation, fault detection, and fault accommodation in energy processing systems. This includes terrestrial and autonomous power systems, as well as electric drives and power electronic systems, as found in civilian and military sectors. In particular, this project aims at making connections with traditional fault tolerance techniques by developing distributed monitoring/correcting schemes and by explicitly accounting for the system dynamics before overcoming faults that affect the functionality of the system.


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This research project deals with issues arising in controlling and monitoring real-time systems over heterogeneous communication networks. The project aims at studying the performance of variants of state feedback control schemes in a network setup where packets can be lost or delayed due to deteriorating network performance. In particular, the project studies the tradeoffs that arise between system instability, noise level, link delay, and packet dropping probability.

**Operation and Control of Energy Processing Systems: State Estimation in Switched Linear Systems**

C. N. Hadjicostis,* S. Sundaram
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*National Science Foundation, ITR 02-24729 EPNES*

This project develops observer methodologies for switched linear systems that are driven by unknown inputs. The methodologies are based on using (possibly delayed) outputs, and knowledge of the switching sequence and the system dynamics in order to decouple the unknown inputs from the observer error.
An Integrated Approach to Fault Tolerance in Discrete-Time Dynamic Systems
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National Science Foundation, ECS 00-92696 CAREER

This project develops systematic approaches for modeling, detecting, identifying, and correcting faults in order to ensure the proper functionality of discrete-time dynamic systems or networks. The project takes a system-theoretic viewpoint and aims to characterize the fundamental limitations of fault-tolerant designs by jointly exploiting system-, coding-, and information-theoretic techniques.

A Robust Control Approach to Digital Communications
C. Hadjicostis,* P. Voulgaris,* R. Touri
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National Science Foundation, CCR 00-85917 ITR

This project develops a deterministic worst-case framework for reconstruction of discrete (source) data transmissions through dispersive communication channels. This framework can be explored based on robust control ideas and formulations and serves as a complement to existing approaches that reconstruct data by optimizing probabilistic criteria.

Data Centric Sensor Networks
J. Hou,* P. R. Kumar, L. Sha
National Science Foundation, ANI 02-21357

Conducted in the Digital Computer Laboratory and the Coordinated Science Laboratory

This project addresses sensor networks.

Communicating Networked Control Systems
P. R. Kumar*
U.S. Army Research Office, Multidisciplinary Research Program of the University Research Initiative, DAAD19-01010-465

The goal of this project is to investigate the modeling, analysis, design, and control of communicating networked systems of sensors and actuators on fixed and mobile platforms.

Data Centric Sensor Networks
P. R. Kumar*
National Science Foundation

Conducted in Coordinated Science Laboratory

This project addresses issues related to sensor networks, formed by nodes that can sense, wirelessly communicate, and compute.

Efficient Resource Management for Controlled Mobility Wireless Networks
P. R. Kumar*
National Science Foundation

This project addresses the design, development and operation of networks that are mobile.

Quality of Surveillance and Control
P. R. Kumar*
Defense Advanced Research Projects Agency, Multidisciplinary Research Program of the University Research Initiative, N00014-01-1-0576

The objective of this proposal is to create a scientific foundation for the distributed optimization problem of surveillance and control.

Towards a Theory of In-Network Computation for Surveillance and Monitoring in Wireless Sensor Networks
P. R. Kumar*
National Science Foundation

This project addresses the development of a theoretical foundation for sensor networks.

A Network Virtual Machine for Real-Time Coordination Services
P. R. Kumar*
Defense Advanced Research Projects Agency, F33615-01-C-1905

The goal of this proposal is the creation of a real-time network coordination and control layer (middleware) that abstracts, controls, and ultimately guarantees the aggregate behavior of large unreliable networks such as those composed of sensors and actuators.

Scalable Multilayer Control of Joint Battlespace Networks
P. R. Kumar*
U.S. Air Force Office of Scientific Research, F49620-02-1-0217

This project addresses issues relating to communication networks, both wireless radio and free-space optical.

Hybrid Supervisory Control of Uncertain Nonlinear Systems
D. Liberzon*
University of Illinois Research Board

Hybrid systems are systems that combine continuous and discrete dynamics. This research is concerned with problems of the following kind: given a process, typically described by a continuous-time system, find a hybrid

* Denotes principal investigator.
controller such that the closed-loop system displays some desired behavior. An important situation in which such a control paradigm is useful arises when the model of the system contains large-scale uncertainties. Logic-based switching introduced together with, or even instead of, more traditional continuous tuning has been shown to improve performance and has become quite popular in the recent adaptive control literature. Such control techniques are also much more amenable to computer implementation. However, a vast majority of the results available on this subject are limited to linear systems. The primary goal of the proposed research is to develop systematic tools for hybrid control design, applicable to useful classes of nonlinear uncertain systems.

Hybrid Control of Nonlinear Systems
D. Liberzon*
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National Science Foundation, ECS-0134115

The research and educational development plan proposed here is aimed at designing hybrid control algorithms. In this framework, a continuous-time process is controlled by means of logic-based switching among a family of regulators. The closed-loop system is then called hybrid because it combines continuous and discrete dynamics. We study several situations in which such a control paradigm is natural and helps overcome various shortcomings of more traditional control methodologies. The primary focus of this research is on systematic development of tools for hybrid control design, applicable to general and useful classes of nonlinear dynamical systems.

Multiple View Geometry
Y. Ma*
University of Illinois

The goal of this project is to unify the study of geometry of multiple images into a simple and clean mathematical framework where efficient algorithms and systems can be developed for applications in computer vision, robot vision, computer graphics, cognitive science, and so forth.

Adaptive Methods for Heterogeneous Wireless Services
S. Meyn,* M. Medard, J. Huang
National Science Foundation, NSF CCR 99-79381, NSF ITR 00-85929

With communication and computing systems becoming increasingly pervasive, future systems will require the ability to accommodate, in real time, wireless services to support a variety of applications ranging from traditional voice and paging services to nomadic computing applications. Different services such as voice, or data, may have vastly different requirements in terms of burstiness, or rate and quality of service (QoS) requirements. We consider coding, routing, and traffic rate mechanisms to provide smooth heterogeneous services to a variety of users via wireless access to a network.

Control Techniques for Complex Networks
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National Science Foundation, ECE-02-17836

In many application areas and in many scientific disciplines, one seeks methods for managing complexity of man-made or real-world systems. Famous application areas include network management in production systems and wireless networks; analysis of the stability of candidate pharmaceutical compounds; and the relationship between chromosomal and protein structure. This project concerns several interrelated approaches to managing complexity in large interconnected systems. Specific application areas addressed in the proposal include phase transitions in molecular models and resource allocation in large network models.

Large-Scale Simulation of Manufacturing and Communication Systems
S. Meyn,* S. Henderson (Cornell University)
National Science Foundation, DMI-0085165

In the past decade, we have seen astonishing growth in both the theory and application of queuing networks. Industry is driving research in communication and data networks, computer systems, and manufacturing systems. Semiconductor manufacturing plants and the Internet are two infamous examples of networks of almost unimaginable complexity. A powerful need exists for methods for deriving and evaluating operational policies that may be used to effectively drive these systems. This project sets out to develop methods for control synthesis and evaluation for truly complex networks.

Visualization and Optimization Techniques for Analysis and Design of Complex Systems
S. Meyn*
National Science Foundation, ECS-0228251

This project concerns several interrelated approaches to managing complexity in large interconnected systems. The focus of this project is resource allocation in large network models. A related project concerns phase transitions in molecular models. This research will provide new design methodologies and efficient approaches to simulation and online tuning of control algorithms.

* Denotes principal investigator.
An Integrated Exploration of Wireless Network Communication

S. Meyn*
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National Science Foundation, ITR-00-85929

This research studies the design of agile wireless networks that accommodate time variations in the communication channels, the information sources, and the network topology. The research will lead to design principles that, in addition to enabling more efficient use of the current cellular and PCS bands, will allow exploitation of frequency bands in the 10-100 GHz range to provide high-speed multimedia services for both indoor and outdoor applications.

Passivity-Based Control in Bipedal Locomotion

M. W. Spong, J. Holm, D. Herring, J.-S. Moon, A. Block, T. Filipiak
National Science Foundation Grant 0510119

The project explores bipedal locomotion in the context of passivity based hybrid nonlinear control. We are investigating speed regulation, the use of alternate potential functions to increase the basins of attraction of stable limit cycles, the effect of control saturation and underactuation in passivity based control, and the efficiency of passivity based control methods compared to true energy optimal control. The goal is to help solidify the foundations of the field through analysis, development of new concepts, and the design of provably correct control algorithms.

Telemanipulation in Multi-Robot Networks

Office of Naval Research, Grant N00014-05-1-0186

In this project, we are addressing fundamental issues in communication, coordination, and teleoperated control of multiple agents in coordinated manipulation tasks. While multiagent coordination and control problems such as swarming, flocking, and rendezvous have been studied by several researchers, much less work has gone into the teleoperated control of multirobot networks, especially when the multirobot network is expected to engage in tasks involving both manipulation and motion coordination. Manipulation tasks require haptic and force feedback that introduce significant stability and transparency problems with respect to communication delay, packet loss, and other communication effects.

U.S.-France Cooperative Research: Passivity Based Control of Networked Control Systems

M. W. Spong,* R. Ortega (CNRS, France)
National Science Foundation Grant 0128656

This award supports U.S.-France collaboration in control systems between Mark W. Spong of the University of Illinois and Romeo Ortega of the Signal and Systems Laboratory at SUPELEC, a French center for research in electrical engineering. The objective is to investigate passive nonlinear control of networked control systems, in particular, systems involving bilateral remote operation (teleoperation) over unreliable communication networks. The problem is motivated by interest in wireless communication in imbedded real time control systems and the use of the Internet as a communication medium in teleoperated and networked control systems.

Reliable and Robust Control of Formations of Unmanned Vehicles

D. Stipanovic,* M. W. Spong,* P. Hokayem, C. Burns, J. Mejia
The Boeing Company

This project is to develop reliable and robust control architectures for networks of autonomous aerial and ground vehicles. The aim is to develop control laws that have low sensitivity to noisy and lossy data communication among vehicles, that are scalable in terms of number of vehicles, and that have the ability to handle discrete transitions in the network, such as formation reconfiguration, addition or loss of vehicles from the formation, and so forth. Applications of this work include undersea and planetary exploration, search and rescue, air traffic control, and control of sensor networks. Both theoretical and experimental issues are being investigated.

Protocols for Mobile Ad Hoc Networks

N. Vaidya*
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National Science Foundation, ANI 01-96410

Mobile ad hoc networks are multihop wireless networks, with dynamically changing network topology. In this project, we investigate several protocol design issues corresponding to routing, medium-access control, and transport layers in mobile ad hoc networks. The focus is on performance issues related to individual layers as well as interlayer interactions.

* Denotes principal investigator.
TCP-Unaware Approaches to Improve Performance of TCP Over Wireless Links
N. Vaidya*
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National Science Foundation, ANI-01-96413

The focus of this project is on TCP-unaware techniques to improve TCP performance over paths that include wireless links. The path from a TCP sender to a TCP receiver usually includes several intermediate nodes that may drop TCP packets if congestion occurs. TCP makes the implicit assumption that all packet losses are due to congestion. Since wireless links are prone to transmission errors, this assumption is not accurate for TCP over wireless links. Nevertheless, TCP reduces its congestion window when packet losses due to transmission errors occur. This phenomenon is known to result in poor throughput for TCP over wireless links. This project investigates TCP-unaware mechanisms to avoid such TCP performance degradation.

Design Theory and Methodology

Integrating Electrical, Economic, and Environmental Factors into Flexible Power System Engineering
P. Krein, P. Chapman, M. Pai, P. Sauer (Elect. & Comput. Engr.); D. Thurston*
National Science Foundation

A flexible power system is one in which redundancy and reliability are managed through localized control, distribution of energy sources, shifting among available sources, treating loads as a potential resource for operations and control purposes, and directing energy to the most critical needs. This project seeks to establish a firm science-based framework for integrating electrical, economic, and environmental factors into flexible power system design.

Digital Signal and Imaging Processing

Efficient Algorithms for Lossless Data and Image Compression
Y. Bresler,* D. Baron
National Science Foundation, CCR-0122293

In spite of the focus in recent years on lossy compression of audio, images, and video, lossless data compression remains crucial in applications such as text files, facsimiles, software executables, and medical imaging. Universal source coding algorithms, which deal with sources whose statistics are unknown, are of particular importance. The main goal of this research is to develop algorithms featuring fast computation and low memory use, while providing compression quality near the fundamental theoretical bounds. The resulting algorithms will have linear complexity and will be better than any current algorithm with comparable asymptotic compression performance, in terms of computation and/or memory use. Some versions of these algorithms will also have simple structure, admitting fast hardware implementations. A special focus of this research is also on parallel algorithms that allow arbitrary speedup while maintaining the same compression quality.

Fast Algorithms for 3-D Cone-Beam Tomography
Y. Bresler,* J. Brokish, A. George
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National Science Foundation, CCR-0209203

In cone-beam tomography, projections are acquired by an area detector, using a source of divergent rays traveling on one of several possible trajectories. It is already used in current PET and SPECT scanners and in nondestructive evaluation (NDE) in manufacturing, and it will be the basis for the next generation of diagnostic CT scanners. This will allow use of CT as a dynamic imaging modality for cardiac imaging, or for real-time surgical guidance in medicine, or as a high-throughput NDE system in manufacturing, or as a high-accuracy security baggage scanner in airports. Unfortunately, the high computational cost of current cone-beam reconstruction algorithms constitutes a major barrier to their applications. We are developing new image reconstruction techniques that require only computations for an image. These techniques can be 100 times faster than current methods for typical images and promise to overcome the computational bottleneck in 3-D cone-beam CT, helping to make it a feasible and commercially viable technology for wide use.

Fast Algorithms for Tomography
Y. Bresler,* S. Basu, F. Charpentier, J. Brokish, A. George
National Science Foundation, CCR-9972980

Computerized Tomography (CT) is the principle underlying most of the key diagnostic imaging modalities and many other imaging techniques, including synthetic aperture radar. We are developing new image reconstruction techniques that require only computations for an image, as compared to computations for the current method of choice, the filtered backprojection (FBP). These techniques are orders of magnitude faster than FBP for typical images and promise to overcome the computational bottleneck created by new imaging technologies that acquire large quantities of data in real time. Similar

* Denotes principal investigator.
developments are pursued for iterative and for 3-D reconstruction.

**Minimum-Redundancy Spatiotemporal MRI**
Y. Bresler,* Z. P. Liang,* N. Aggarwal

*National Science Foundation, BES-0201876*

Since its inception in the early 1970s, magnetic resonance imaging (MRI) has become a premier diagnostic imaging tool. Although its early applications were largely limited to stationary objects, MRI has also proven extremely useful in recent years for dynamic imaging applications, such as cardiac, functional, or interventional imaging. An important challenge confronting dynamic MRI (D-MRI) is to obtain both high spatial and high temporal resolution, with three dimensional imaging capability. The goal of this research is to develop, implement, and test rigorously a new unified theoretical framework for minimum-redundancy D-MRI data acquisition and image reconstruction. In this framework, dynamic imaging is treated as a higher-dimensional image reconstruction problem, with time being an independent axis. Instead of attempting to freeze all motion by sufficiently fast acquisition, time variation during acquisition is explicitly accounted for in the steps of MRI sequence design, data acquisition, and image reconstruction. The approach draws on and extends theories and algorithms introduced by the researchers over the past few years and offers the potential for significant speedups of the imaging process. Furthermore, combination of the theory and techniques developed in this project with fast-scan methods and with methods based on phased-array RF coils will produce combined speedups, greater than any one of the individual approaches.

**Unwrapping Phase Images**
R. Koetter,* D. C. Munson,* Z. P. Liang*

*National Science Foundation, CCR 01-05719*

The primary goal of the project is to develop optimal algorithms for the long-standing problem of unwrapping phase images from various imaging modalities such as SAR and MRI. Probabilistic inference algorithms will be developed and tested using SAR and MRI as testbeds. Prof. Liang is responsible for phase unwrapping of MRI data.

**Brain Image Segmentation by Integrated Multiscale Analysis and Shape Deformation**
Z. P. Liang,* S. Wang

*NEC Research Lab; University of Illinois Research Board*

Conducted in the Beckman Institute for Advanced Science and Technology

Brain image segmentation is an important and challenging engineering problem confronting brain mapping. By accurately segmenting gray-scale brain images into various brain structures, we will be able to effectively visualize three-dimensional brain structures and carry out meaningful neuromorphometric studies. The long-term goal of this project is to develop and implement a unified processing software platform to effectively support various information processing tasks in neuroimaging or brain mapping. The specific aim of the project is to capitalize on our recent, novel work on graph-based multiscale image analysis and shape deformation to produce an efficient, accurate, and reliable algorithm for identifying brain structures from MR images. We expect to accomplish three specific tasks during the project period: complete the development of a novel graph-theoretic algorithm for multiscale analysis of MR brain images; further develop, perfect, and validate a topology-preserving shape deformation algorithm so that prior shape information of brain structures can be incorporated into the image segmentation process effectively; and integrate multiscale analysis with shape deformation for accurate segmentation of brain images and develop a prototype software system to facilitate the application of the developed algorithms for practical applications in brain mapping.

**Model-Based Tomographic Imaging Methods**
Z. P. Liang,* J. Ji, Y. Bresler*

*National Institutes of Health, R21 HL62336*

The mathematical basis of tomographic imaging is conventionally rooted in the well-established Fourier or radon transform theories, so that image quality is mainly dependent on how the data space is sampled. In practice, physical and temporal constraints often prevent a sufficient coverage of the data space, resulting in various image artifacts, such as Gibbs ringing, resolution degradation, and various motion effects. This project is aimed at overcoming these problems by developing new model-based imaging techniques that can incorporate a priori information into the imaging process effectively. Application of these techniques to cardiac imaging and functional brain mapping is also addressed.

* Denotes principal investigator.
Multisensor Information Fusion
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Defense Advanced Research Projects Agency, MDA972-00-1-0020
Conducted in the Micro and Nanotechnology Laboratory
This project is a component of research conducted in the Center for Bio-Optoelectronic Sensor Systems (BOSS). The primary mission of this center is to develop sensor and processing technology for detection of biochemical agents in battlefield situations. Prof. Liang is responsible for developing statistical algorithms for multisensor information fusion.

Statistical Image Reconstruction
Z. P. Liang,* C. Potter, B. Carragher
National Institutes of Health, RO1 GM61939
Conducted in the Beckman Institute for Advanced Science and Technology
The primary goal of the project is to develop practical image reconstruction methods for high-resolution imaging from electron microscopy data, particularly in the presence of uncertainties in data acquisition parameters (a projection angle for example). We formulate the problem as a statistical parameter estimation problem by introducing a proper model for the object (for instance, a virus) to be imaged. This research effort promises to provide a brand-new solution to the long-standing problem in electron microscopy.

Electromagnetics

Miniaturized Antennas in Random Sensor Arrays for Planetary Surface and Atmosphere Exploration
J. T. Bernhard,* A. C. Singer, P. E. Mayes, E. Michielssen jbernhar@uiuc.edu
National Aeronautics and Space Administration, NAG3-2840
In this project, we are developing size-appropriate, electrically small (miniaturized) antennas with moderate bandwidths for such sensors as well as processing algorithms for random arrays that enable the sensors to work together to communicate their data to remote collection sites regardless of their relative positions or orientations. The array will configure itself to form a beam in a general direction that can be intercepted by a passing orbiter or directed to a particular satellite- or surface-based receiver. The project will culminate with a testbed demonstration using the developed antennas and processing algorithms.

Human–Computer Interfaces

Adaptive/Reflective Middleware System
R. Campbell,* K. Nahrstedt,* R. Kravets,* L. Sha,* J. Tanner, P. DeRose
Defense Advanced Research Projects Agency Grant, INT NBCH 1030017
Lockheed-Martin; BBN Technologies; Johns Hopkins University; Scientific Research Corporation; Telecordia; Conducted in the Digital Computer Laboratory
The ARMS project investigates Multi-Layer Resource Management for next generation Navy battleships. This collaborative effort is developing a system that encompasses many major aspects of computing resource management. Our team's focus is the management of the human element of mission tasks, identifying and tasking the best user for each task, and locating the best hardware to perform that task within a distributed system platform. Intelligent algorithms dynamically adjust to current conditions when selecting users and also learn from a user’s previous performance. We are integrating current research in pervasive computing, allowing users to perform their tasks more efficiently by allowing them mobility that existing systems lack.

Interfaces

Atomistics of Growth and Transport at Metal and Semiconductor Surfaces
U.S. Department of Energy, DEFG02-91ER45439
In cooperation with the Frederick Seitz Materials Research Laboratory
The individual atomic events contributing to the growth of crystals and films are being explored on the atomic level. Through the use of the field ion microscope, single atoms are visualized, and processes such as condensation, diffusion, nucleation, and incorporation into the lattice are examined quantitatively to reveal how structure and chemical composition affect growth processes.

* Denotes principal investigator.
Magnetic Resonance

Constrained Spectroscopic Imaging
Z. P. Liang,* P. C. Lauterbur*
National Institutes of Health, 1R01CA51430-01A4

Conducted in the Beckman Institute for Advanced Science and Technology

Magnetic resonance spectroscopic imaging promises to provide an entirely new way to examine the dynamics of human biochemical processes in vivo noninvasively. However, its practical applications have been limited because of low sensitivity and long imaging time. The primary objective of this research is to develop mathematical methods to effectively utilize the readily available anatomical information to constrain the spectral distribution to reduce imaging time without compromising spatial resolution.

Functional Brain Imaging
Z. P. Liang,* J. Ji
National Science Foundation, BES 95-02121; Beckman Institute for Advanced Science and Technology

Conducted in the Beckman Institute for Advanced Science and Technology

The primary objective of this project is to develop new signal-processing algorithms for detecting brain activities from functional MRI data. Researchers are investigating a wavelet-transform-based filtering and t-test method for signal detection and a multiscale method for image registration and motion correction.

MR Imaging of Time-Varying Objects
Z. P. Liang,* Y. Bresler,* J. Ji, A. Sen Gupta, A. Guo
National Science Foundation, BES 95-02121; National Institutes of Health, NIH-R21-HL062336

Conventional MR imaging techniques have been widely used to obtain high-resolution images from stationary objects. For time-varying objects such as the beating heart, however, significant image artifacts often arise that render the image useless. This project aims to develop a new class of data acquisition and image reconstruction methods for real-time imaging of cardiac structures and functions.

Materials Chemistry

Metal Boride Thin Films: Synthesis of New Molecular Precursors and Growth by Remote-Plasma CVD
National Science Foundation

We synthesize new single-source precursors and deposit thin films of the "metallic ceramic" compounds ZrB$_2$, HfB$_2$, and CrB$_2$ that are technologically attractive as hard, wear-resistant coatings and as diffusion barriers in ULSI microelectronics. We also deposit films of the 39K superconductor MgB$_2$. Our approach, remote-H$_2$ plasma chemical vapor deposition, combines the best features of the chemical and physical deposition routes: the high rate and conformal coverage characteristic of CVD, and the low substrate temperature characteristic of PVD. The research includes analysis of the growth chemistry using real-time spectroscopies and evaluation of the resulting film properties and performance.

Nanoscience and Technology

Thermodynamics of Nanostructures and Buried Interfaces Using Scanning Nanocalorimetry
L. H. Allen*
National Science Foundation, DMR 0108694

This project aims to investigate a variety of basic materials issues in thin films and at interfaces, such as coalescence during initial stages of film growth and silicide formation with restricted dimensions. The research also seeks to reveal new thermodynamic information about behavior of materials at nanometer length scales. The research will contribute basic materials science knowledge at a fundamental level to important aspects of electronic/photonic materials.

Evolution of Stress and Mass Transport During keV Ion Bombardment
D. G. Cahill,* R. S. Averback,* K. Zhao
National Science Foundation, DMR-0419840

Ion beams with energies on the order of 1-10 keV are widely used for etching of surfaces, microanalytical methods, and shallow dopant implantation. We are using sensitive measurements of micro-cantilever bending to measure the changes in stress produced by keV ion bombardment of metal and oxide thin films. These data will allow us to test ideas of how ion beams modify film stress

* Denotes principal investigator.
and the nanoscale morphology of surfaces through rippling, dewetting, and ion-beam induced viscous flow.

Materials Physics of Aqueous Interfaces
D. G. Cahill,* S. Putnam, X. Zhang
NSF-STC Center of Advanced Materials for the Purification of Water with Systems, National Science Foundation Agreement CTS-0120978

We are developing and applying novel methods for probing the thermodynamics of material interfaces with water. The bending of microfabricated cantilevers gives a quantitative measurement of the aqueous interface stress; i.e., the derivative of the surface energy with respect to elastic deformation. A highly sensitive optical probe of surface curvature is providing data on the changes in oxide/water interface stress produced by changes in the composition of fluid mixtures. ThermoDiffusion, the transport of mass in a temperature gradient, is being applied to polymer-nanoparticle suspensions. The Soret coefficient gives a measure of the local change in water enthalpy that is produced by the proximity of a solid surface. Rutherford backscattering spectroscopy is used to measure the partitioning of ions and heavy metal contaminants in commercial RO and nanofiltration membranes.

Thermal Conductance of Interfaces and the Thermal Conductivity of Multilayer Materials
D. G. Cahill,* C. Chiritescu, Y. K. Koh
Office of Naval Research N00014-05-1-0250

We are studying the transport of heat across solid-solid interfaces and the thermal conductivity of nanostructured materials. Our objective is to explore the connections between interface structure and transport, and the possibility of producing materials with a significant fraction of localized vibrational modes. The thermal conductivity of thin films, multilayers, and individual interfaces are characterized by picosecond time-domain thermoreflectance. We have recently observed ultralow thermal conductivities in nanoscale multilayers of refractory metals and alumina.

Thermal Transport at Solid-Liquid Interfaces
D. G. Cahill,* Z. Ge, P. V. Braun
U.S. Department of Energy, DEFG02-01ER45938

We are studying the heat-flow across solid-liquid interfaces using ultrafast optical metrology. The thermal conductance of interfaces controls the performance of novel heat transfer fluids and provides fundamental information about the bonding and structure of interfaces. Nanoscale colloidal metal particles serve as the heaters and thermometers in the experiments: metal particles are heated by the femtosecond pulses of the pump beam and the temperature decay is probed by transient optical absorption. By adding molecular terminations to surfaces and nanoparticles, we probe the heat flow through molecular monolayers and the interfaces between organic layers and water.

Ultrafast Laser Interactions with Thin Films, Surfaces, and Interfaces
D. G. Cahill,* F. Watanabe, J. Letcher
U.S. Department of Energy, DEFG02-ER9145439

We are studying the interactions of ultrafast optical pulses with materials through studies of laser-assisted field evaporation, thermal transport using extremely large temperature excursions, and the morphologies of ablation craters formed on transparent, crystalline oxides. A time-of-flight mass spectrometer is used to measure the mass and flux of atoms emitted from a biased tip subjected to mJ optical pulses of 100 fs duration. Pump-probe measurements of optical reflectivity and Raman vibrational spectra enable us to probe the evolution of electron and phonon temperatures and strain on picosecond time-scales.

Networking

Ad hoc Wireless Communication Between Vehicles
R. H. Campbell,* S. Myagmar
Motorola, Inc.
Conducted in the Digital Computer Laboratory

We propose an ad hoc routing protocol with location service for vehicle-to-vehicle communication. As an example of feasibility, we developed and tested application prototypes of voice chat, location filtering, and roadside information service for moving vehicles. Our protocol takes into account the motion of vehicles on a highway. It broadcasts location updates only when the velocity or direction of a vehicle "space reservation" to avoid transmission collisions.

Data-Centric Sensor Networks
J. C. Hou,* L. Sha, P. R. Kumar, N. Li, H. Zhang
National Science Foundation, Special Projects in Networking, ANI-0221357
Conducted in the Digital Computer Laboratory

In this research project, we first lay an integrated framework in which a comprehensive solution can be designed that comprises a set of component solutions at each layer to achieve the targeted goals of data-centric
sensor networks. Then, we consider under this unified framework, research issues along the following thrusts of research: hierarchical cluster formation and routing; topology control and power management; Quality-of-Service provisioning within/between clusters; MAC design for timely dissemination of delay-sensitive data; and empirical study with the use of Motes.

A Component-Based Software Environment for Simulating and Synthesizing Network Protocols in Large-Scale Networks
J. C. Hou,* R. Campbell, L. Kung, H. Kim
University of Illinois

Conducted in the Digital Computer Laboratory

In this project, we propose to design, implement, and evaluate a component-based software environment for a wide variety of emerging network architectures and applications. The environment expedites execution and simulates, emulates, and synthesizes network protocols and services in a systematic manner. We follow three research thrusts: We extend JavaSim to include base classes and packages for grid networking technologies. We investigate issues of parallelizing real-time process driven simulation engines and explore the use of fluid models, network calculus models, and rescaling techniques to expedite simulation. In a related project, we build a software-programmable router platform, called CROSS, that is dynamically extensible, configurable, and able to predictably process network flows that require QoS-aware access to multiple resources. We will leverage JavaSim components as building blocks for CROSS/Linux router services, and realize differentiated multicast and secure video proxy systems as CROSS services.

Application/System Quality-of-Service (QoS) Interface Capabilities
K. Nahrstedt,* W. J. Jeon, B. Kalter, J. H. Seo
National Aeronautics and Space Administration, NAG 2-1250

Conducted in the Digital Computer Laboratory

Researchers are investigating application-system Quality-of-Service (QoS) interface capabilities for visual tracking distributed applications. The interface between the application and the underlying QoS-aware resource management system must provide several important functionalities: application QoS application programming interface, translation between the application QoS into the system QoS parameters, integrated reservation coordination policies and protocols to avoid and prevent deadlock situations, adaptation policies and their application enforcement, and others. These functions will reside in the end-system management entity called the QoS Broker, which represents the application/system interface for provision of end-to-end QoS guarantees.

Hybrid Adaptive Algorithms for End System Middleware
K. Nahrstedt,* B. Kalter, B. Li

Conducted in the Digital Computer Laboratory

Current distributed multimedia applications demand Quality-of-Service (QoS) from the supporting system. However, within the QoS demands, lower level transport facilities may not constantly provide guaranteed QoS without perturbation. In this scenario, researchers are investigating hybrid adaptive algorithms in the middleware level of end systems to perform QoS adaptation on a critical QoS metric. The research concentrates on analysis of QoS adaptation in dependence of system resource availability changes by applying theories from digital control systems.

QoS Routing
K. Nahrstedt,* J. Qian, L. K. Shan

Conducted in the Digital Computer Laboratory

The task of Quality-of-Service (QoS) routing is to find a path in the network that satisfies constraints on such metrics as bandwidth, delay jitter, and cost. This study focuses on QoS routing algorithms and their design within routers. The problem of finding a path with constraints on two or more additive metrics (delay and delay jitter) is NP-complete. This research concentrates on heuristic algorithms and study of the family of distributed and hierarchical routing algorithms to solve the multiconstrained routing problem. The QoS routing solutions are applied to point-to-point as well as multicasting scenarios.

QoS-Aware Resource Management
K. Nahrstedt,* K. Kim, A. K. Viswanathan, J. Wang
Partnerships for an Advanced Computational Infrastructure

Conducted in the Digital Computer Laboratory

Operating systems and communication systems need new algorithms, services, and protocols to support processing of audio/visual streams according to Quality-of-Service (QoS) specification. This project concentrates on the CPU brokerage service with advanced reservation, admission,
scheduler, and adaptation control for soft real-time and non-real-time tasks. At the communication level, researchers provide IntServ bandwidth brokers in the edge networks and DiffServ brokers within the backbone routers to provide end-to-end guarantees.

Operating Systems and Security

Choices: A Reliable and Secure Operating System for Mobile Devices
R. H. Campbell,* J. Hou,* Z. Anwar
National Science Foundation, CNS 03-05537

Distributed denial of service, man-in-the-middle attacks, message tampering, eavesdropping, and replaying threaten to cripple the Internet infrastructure. They are especially harmful to killer applications for the Internet such as voice over IP (VoIP) and voice over wireless. There is a need to develop innovative strategies to detect, mitigate, and counter these threats. Unfortunately various key components are required to realistically model a large VoIP infrastructure and study its vulnerable spots. J-Sim is a composable and extensible network simulation and emulation environment. We extend J-Sim to include representative security mechanisms/policies for VoIP such as IPsec, firewalls, Media Gateways, Soft Switches, key distribution and authentication mechanisms, and popular VoIP protocol stacks such as RTP, SIP, and H.248. We also provide various attacker models and IDS mechanisms to allow vendors to plug in their VoIP components and test them for vulnerabilities in a controlled and simulated environment before actual deployment. In addition we are exploring the use of virtualization techniques and reference monitors to choose secure paths for VoIP information flows.

Composing Security in Large-Scale Cyber-Infrastructures
R. H. Campbell,* S. R. Katasani
National Science Foundation

Present day cyber infrastructures like the power grid are very complex assortments of various devices with different security requirements and differing ability to provide security. Not all the devices in the system can provide the necessary security according to the enterprise policies, but the presence of these devices is indispensable. In such a scenario, it is really difficult for the system managers or the system administrators to monitor and maintain these devices. We are developing a methodology that will allow a system administrator or a manager automatically to analyze the system and reason about the security and decide the necessary security measures to install. In order to achieve this goal, we developed a representation for modeling the cyber assets of an organization based on workflows and common information models. In our modeling formalism an organization can be defined as a combination of subjects, objects, services, tasks, and communication protocols.

ITR: Active Information Spaces Based on Ubiquitous Computing
National Science Foundation, CCF-00-86094

The project researches a new form of operating system to manage a model of computing called an Active Space. This model integrates physical spaces that contain ubiquitous computers into a computational environment that supports human activity and applications. The physical space, augmented with communicating computer devices, becomes a distributed computing system. Gaia, an operating system for Active Spaces, will accommodate diversity by exploiting standards for interoperation and cooperation. System services track, authenticate, and support mobile users with reconfigurable graphics, multimedia, and Active Space applications. A unifying object bus, component model, and adaptive stream model extends plug and play to distributed mobile computers within physical spaces like cities, buildings, and rooms. Active Spaces have the potential for creating multibillion dollar industries. Automated surgery, collaboration, and engaged learning are a few of the compelling examples.

Mobile Sensor-Network Authentication
R. Campbell,* V. Welch,* C. Andrews, P. Naldurg, H. Khurana
Office of Navy Research

Authentication is a critical security requirement for sensor network nodes and provides a high quality of assurance in a hostile deployment scenario, when it is important for a data-gathering source to confidently verify the origin of sensor data. We focus on higher-end sensors that have significantly more processing power and memory than first-generation sensors. We question some of the existing weak cryptographic protocols and investigate the feasibility of using limited public-key encryption to address the sensor origin authentication problem. The

* Denotes principal investigator.
challenge of key distribution is addressed by imprinting sensors with public key certificates, as well as the corresponding private keys, before being deployed. A line-of-sight transmission may be used to update the key.

Security and Configuration of Software Defined Radios
R. H. Campbell,* S. Myagmar
Various Donors

Reconfigurability of software defined radios (SDR) supports integration and co-existence of multiple radio access technologies on a general-purpose radio equipment. An SDR terminal is able to switch its operating mode by configuring its radio parameters and component composition to suit the appropriate radio access technology, user preferences, and local conditions. The main challenges are how to provide a methodology to dynamically and securely configure software components originating from several, different vendors, and how to remotely attest the validity of the radio configuration to external parties such as a network operator or service provider.

Optical and Discharge Physics

Startup Processes in Metal Halide Lamps
J. G. Eden,* M. J. Kusher, R. Moss, A. Bhoj, T. Sommerer (GE)
General Electric R&D Center

Conducted in the Everitt Laboratory

High pressure, metal halide lamps are typically the lighting sources used for street lamps, stadiums, warehouses, and other large indoor arenas. Metal halide lamps start as room temperature, glow discharges. Upon heating, metal-halide compounds in the lamps vaporize to generate multiatmosphere pressure plasmas, which then produce nearly continuum radiation. The starting process usually involves applying high-voltage pulses to tens to one hundred Torr of Ar gas with a small admixture of mercury or another low ionization potential rare gas. Optimizing this process will ultimately produce longer lived, more reliable lamps. In this research project, advanced computer modeling and laser diagnostics are being used to investigate the fundamental plasma processes that occur during startup of metal-halide lamps. Of particular interest are the plasma-surface interactions on the cathode that result in sputtering of cathode materials. Methods to minimize sputtering without using costly exotic materials are being formulated.

Optical Imaging

Optical Biopsy of Cancer using Optical Coherence Tomography
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Conducted in the Beckman Institute for Advanced Science and Technology

The high-resolution, real-time imaging capabilities of optical coherence tomography (OCT) allow for the acquisition of "optical biopsies" of tissue. Images approaching the level of histology can be acquired without the physical resection and processing of tissue that is common practice today. A compact and portable OCT system is being constructed for clinical use in local hospitals and at the University of Illinois at Chicago. This system will be used to identify various stages of cancer growth as well as metastases and be compared directly to results obtained with histology, the gold-standard for diagnosis. In certain clinical scenarios, the use of real-time OCT may replace the need for tissue excision and analysis.

Near-Field Optical Power-Extinction Tomography
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U.S. Air Force Multidisciplinary Research Program of the University Research Initiative Grant, F49620-03-1-0379; National Science Foundation Career Award, 0239265

Conducted in the Beckman Institute for Advanced Science and Technology

Near-field optical power-extinction tomography (NOPET) represents the intersection of total internal reflection tomography (TIRT) and optical power-extinction tomography (OPET) where the probe beams of OPET are replaced with evanescent waves as in TIRT for sample illumination. With this technique it is possible to produce sub-wavelength resolved tomographs of scattering objects from the power lost from the probe fields.

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Near-Field Scanning Optical Tomography
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Near-field scanning optical tomography (NSOT) explores the extension of imaging modalities such as photon scanning tunneling microscopy (PSTM) and near-field scanning optical microscopy (NSOM) to samples that contain three-dimensional structure or when the probe tip is not scanned in grazing proximity to the sample. We solve the linearized inverse scattering problem to produce sub-wavelength resolved tomographs of the object under these conditions.

Optical Power-Extinction Tomography
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Optical power-extinction tomography (OPET) makes use of the power lost from two coherent beams, which simultaneously interrogate a scattering object, to generate a tomograph (three-dimensional image) of that object in a similar manner as computed axial tomography (CAT) makes use of the attenuation of individual beams of x-rays through an absorbing object to generate a tomograph. We are currently developing a prototype instrument. Initial results are promising.

Photon Scanning Tunneling Microscope
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Conducted in the Beckman Institute for Advanced Science and Technology

A photon scanning tunneling microscope (PSTM) is a device where the object is illuminated by an evanescent wave generated at the face of a prism or slide and the field is detected via a fiber probe in the near-zone of the sample (as in near-field scanning optical tomography). The data obtained with a PSTM are not amenable to direct interpretation, but we show sufficient information exists in the raw data to numerically compute the two-dimensional structure of a thin sample, thus achieving a computational lens for the near-field. Demonstration of this work has just been accepted for publication in Physical Review Letters.

Total Internal Reflection Tomography
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Total internal reflection tomography (TIRT) is an imaging modality that makes use of the evanescent waves to illuminate and probe a sample. The probe depth is controlled through the exponential decay of the evanescent wave. In principle, this form of illumination can also enable super-resolved imaging where features smaller than a wavelength can be resolved. To take practical advantage of this capability, it is necessary to solve the inverse scattering problem that is the focus of this project. We are currently constructing an instrument to take the appropriate measurements.

Optical Physics and Engineering

Investigation of Carbon Nanotube Nano-Optics
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Conducted in the Beckman Institute for Advanced Science and Technology

Carbon nanotubes and semiconductor nanowires are tiny objects (1000 times thinner than a human hair) that have recently drawn considerable attention in the scientific and engineering communities because of their novel structural and electrical properties. We will theoretically investigate the optical and optoelectronic properties of these structures.

Arrays of Microdischarges: A New Generation of Lighting Sources

Conducted in the Everitt Laboratory

This experimental and computational program is devoted to investigating diatomic molecules as efficient emitters for lamps. The microdischarge serves as the platform with which a wide variety of diatomics (excimers, metal-halides, etc.) will be studied. A close linkage between
experimental results and theoretical predictions is a key element of this research effort.

**Equipment for Machining of Microdischarge Devices**
J. G. Eden,* C. Herring, J. Gao, A. Oldenburg  
*U.S. Air Force Office of Scientific Research, F49620-99-1-0106*

**Conducted in the Everitt Laboratory**

Under the DOD DURIP program, equipment is being purchased to facilitate the fabrication of microdischarge devices in silicon and other materials systems. A 1-kHz pulse repetition frequency Ti:sapphire regenerative amplifier will be used with an existing oscillator to ablatively machine microchannels in silicon for use in arrays of discharge devices. Also, vacuum ultraviolet optics enabling arrays of sub-50 μm diameter cylindrical channels to be machined in Si metals or SiO$_2$ at 193 nm have been obtained. The introduction of polymer films into these multilayer devices as dielectrics or emission downconverters is another thrust of this program.

**Experimental Studies of Microdischarge Devices and Arrays**
*U.S. Air Force Office of Scientific Research, F49620-99-1-0317*

**Conducted in the Everitt Laboratory**

This research program is focused on fabricating and examining the properties of arrays of microdischarge devices. A variety of processes (wet and dry chemical processing, laser ablation, and ultrasonic milling) are employed to fabricate cylindrical and pyramidal cathodes in silicon as part of a multilayer structure suitable for large-scale production. The properties of arrays and single devices operating in the rare gases are of particular interest, and emphasis is being placed on the characteristics of devices smaller than 50 μm.

**Large Microdischarge Arrays: Diagnostic and Fabrication Equipment**
*U.S. Army Research Office, DAAD19-01-1-0417*

**Conducted in the Everitt Laboratory**

Funds have been provided to purchase equipment for experiments exploring nonlinear optical processes in intense optical fields and the behavior and fabrication of microdischarge devices having dimensions below 100 μm. These equipment items have significantly improved the characterization and functionality of microdischarge devices and arrays fabricated in Si and glass. Improvements in the regenerative amplifier of a Ti:Al$_2$O$_3$ femtosecond system, including its pulse energy and bandwidth, have also been made.

**Microdischarge Arrays: Phase 2**
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*U.S. Air Force Office of Scientific Research, AF EWING TECHNOLOGY 03-1*

**Conducted in the Everitt Laboratory**

The focus of this research program is scaling of microdischarge arrays to $10^4$-$10^5$ devices and emitted power densities of 0.1-1 W-cm$^{-2}$ in the ultraviolet. Arrays are being fabricated in silicon with devices having inverted square pyramidal cathodes and polymer or multicomponent dielectrics. Large arrays have also been successfully constructed and operated in glass in which the pixels are excited with an interdigitated electrode configuration. Several diatomic molecular emitters and excitation processes are under investigation, with initial emphasis on mid- and near-UV emitters.

**Microdischarge Devices and Arrays: Quantum and Coherence Effects**
*U.S. Air Force Office of Scientific Research, F49620-00-1-0372*

**Conducted in the Everitt Laboratory**

A family of photonic devices, known as microdischarges, is being developed under this multiyear program. Based on microplasmas confined to volumes of nanoliters or less, these devices have remarkable properties, including the ability to operate as stable glows at atmospheric pressure and with specific power loadings of several tens of kW-cm$^{-3}$. Single devices and arrays as large as 30 x 30 pixels have been fabricated in silicon, ceramic, and metal/polymer structures. Many applications, including broad-area UV sources, pump sources for microchip lasers, arc lamp ignition, and gas chromatography, are being pursued. Other research thrusts in this program are femtosecond spectroscopy of small molecules by coherent nonlinear optical processes and the study of the optical properties of nanoparticles for lasers and biosensing applications.

* Denotes principal investigator.
Microdischarges and Rare Earth-Doped Waveguide Devices: Visible and Ultraviolet Sources for Lasers and Sensors

Conducted in the Everitt Laboratory

The demonstration of new sources of ultraviolet and visible radiation is the thrust of this research program. Current efforts are two-pronged. Microdischarge devices developed in this laboratory are under study as emission sources for displays or as chemical sensors. Cylindrical and typically 20 to 400 μm in diameter, these microdischarges have properties (VI characteristics, specific power loading) that are unique and quite attractive for a variety of applications. The second facet of this research effort is the study of nonlinear optical phenomena on the sub-100 fs time scale and at intensities exceeding 10^{10} W-cm^{-2}. Using colliding pulse mode-locked and Ti:Al_2O_3 laser systems, wave packet formation, four-wave mixing, and high-order harmonic generation are being studied, both experimentally and theoretically.

Novel Miniature Diagnostic Using Microdischarge Technology
J. G. Eden,* C. Wagner
National Science Foundation; SBIR; SBC ETA UI-99-09-P1

Conducted in the Everitt Laboratory

This SBIR program is developing chemical sensors based on microdischarges fabricated in a "flow through" geometry. Because of the high specific power loadings accessible with microdischarges (> 100 kW-cm^{-3}), arrays of these devices are well suited for the remediation of toxic gases. The emission spectra of gases flowing through a single 100–400 μm diameter microdischarge are presently being studied as a diagnostic of molecular fragmentation in the discharge and as a means of detecting impurities in the gas flow stream.

Spatially-Resolved Detection of Weak Magnetic Fields by Laser Magneto-Optical Techniques
J. G. Eden,* J. Gao,* J. M. Talmadge, R. Roth, A. Fai
U.S. Air Force Office of Scientific Research, F49620-01-1-0546

Conducted in the Everitt Laboratory

M magneto-optical techniques are being developed under this program to detect weak (< 1 nT) magnetic fields for biomedical applications. By employing epitaxial films of novel garnet films in combination with nonlinear optical processes and synchronous detection, magnetic fields as low as 10 nT have been detected reliably.

Visible and Infrared Laser Spectroscopy
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Northrop Grumman Corp.

Conducted in the Everitt Laboratory

Atomic and molecular laser spectroscopy in the visible, ultraviolet, and infrared is the focus of this research effort. Currently, emphasis is being placed on the spectroscopy of the Rydberg states of the neon dimer and rubidium dimers. Excitation spectroscopy of the neon dimer has yielded the first rotationally resolved bands as well as observation of triplet splitting. As a result, structural constants of the molecule have been determined. Femtosecond studies of the dissociation of diatomic molecules, observed in real time, are also being carried out.

Optoelectronics

High-Speed Wavelength-Agile Optical Network
S. L. Chuang,* I. Adesida,* K. D. Choquette,* S. Lumetta*
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National Science Foundation

We propose to explore the architecture and device development issues necessary to develop optical local area networks (LANs) that are ready to interface with optical metropolitan area networks (MANs). Our goal is to develop a clear plan for integration of multiwavelength LANs and MANs in order to improve the degree to which the benefits of high bandwidth in the MANs are delivered to end users on the LANs. Our tasks include the following:

* Denotes principal investigator.
quantitatively evaluate the impact of wavelength conversion on network reliability and study the design of all-optical access architectures that leverage high-speed wavelength conversion and add/drop channel capabilities; design and fabricate tunable laser sources and wavelength converters using composite resonator vertical cavity lasers; design and fabricate a novel semiconductor-based wavelength converter capable of format-transparent and ultrafast wavelength conversion; and design and fabricate add/drop filters and photodetectors.

Parallel Processing

**Intelligent Information Spaces: A Testbed to Explore and Evaluate Intelligent Devices and Augmented Realities**
D. A. Reed,* R. H. Campbell, R. Kravets, M. D. Mickunas, K. Nahrstedt, L. Sha
*National Science Foundation, EIA 99-72884

*Conducted in the Digital Computer Laboratory*

To support information environments where ubiquitous, intelligent devices unobtrusively share data, preferences, and contexts about users and their movement among environments, this project is developing interoperable component architectures for device coordination, seamless object communication for user quality of service, and adaptive user context and modality management. The goal is to define a software architecture capable of enabling a mobile, responsive, and contextual information environment where a broad collection of high-end data display and visualization systems, low-power mobile devices, and "smart" devices with widely varying capabilities are seamlessly integrated using dynamically tailored software components.

Power and Energy Systems

**Extraction of Low-Order Models from Finite Element Representations of Electromechanical Devices**
P. L. Chapman*
*Grainger Center for Electric Machines and Electromechanics*

*Conducted in the Everitt Laboratory*

The finite element method is very effective at accurately modeling magnetic devices such as inductors, transformers, and motors, but is very computationally intense. Several thousand variables are used to describe what should be captured in only a few. In this project, a model reduction method was demonstrated that begins with the finite element technique. The thousands of variables are systematically reduced to only a few, with little loss of model accuracy. This was demonstrated so far for a single inductor. The new model runs several orders of magnitude faster than previous models.

**Fully Integrated Switch-Mode Power Supplies**
P. L. Chapman,* C. Liu
*Grainger Center for Electric Machines and Electromechanics*

*Conducted in the Everitt Laboratory*

A typical switch-mode dc power supply involves several integrated circuits and discrete passive components. By moving all the circuitry to a single integrated circuit, the circuit is reduced in size and potentially cost. Power management and distribution within a chip are better enabled. Several versions of a step-up dc-dc converter have been demonstrated. Newer versions will take advantage of MEMS technology to improve the quality of the passive components and reduce the space occupied by the chip.

**Optimal Diversification of Multiple Energy Sources**
P. L. Chapman*
*National Science Foundation*

*Conducted in the Everitt Laboratory*

The goal is to develop a general approach to the design of a power converter that can interface multiple, unlike, electrical energy sources. The interface would be capable of maximizing or minimizing the energy flow from given sources. The diversification of the energy sources takes advantage of environmentally responsible energy, improves reliability, and potentially reduces cost.

**A Hybrid Systems View of Inverse Problems in Power System Dynamics**
I. A. Hiskens,* D. Liberzon,* M. A. Pai*
*National Science Foundation, NSF ECS-0114725*

*Conducted in the Everitt Laboratory*

Analysis of power system dynamic behavior frequently takes the form of inverse problems, where the aim is to find parameter values that achieve (as closely as possible) a desired response. Examples include parameter estimation, quantifying parameter uncertainty, boundary value problems, and optimal control. The project developed algorithms for solving such inverse problems. Power system behavior inherently involves interactions between continuous dynamics and discrete events. A systematic hybrid systems framework for modeling, analysis, and algorithms was done. The project is completed.

* Denotes principal investigator.
Analysis and Design of Vector Controllers for Induction Machines Using Singular Perturbations
P. T. Krein,* Z. Sorchini
Grainger Center for Electric Machinery and Electromechanics

Conducted in the Everitt Laboratory

An alternative machine model is proposed for the analysis and design of controllers. Based on this framework and using singular perturbation analysis, a sliding mode torque controller is presented. It is shown that under certain restrictions, direct torque control (DTC) can be derived from this controller. The derivation provides insight on dynamics and stability of DTC. In addition to the analysis of established controllers, new controllers are proposed. In particular, a controller based on stator flux is shown to encompass benefits of field oriented control and DTC, while avoiding their limitations. The viability of this new controller is confirmed experimentally.

Coupled Magnetic Applications of Ripple Correlation Control
P. T. Krein,* R. Balog
Grainger Center for Electric Machinery and Electromechanics

Filters based on coupled inductors are promising for use in energy conversion applications because they allow noisy waveforms to be “steered” into filter circuit elements. Previous work enhanced coupled filters through an automatic tuning process that allows peaks or notches in filter characteristics to follow circuit characteristics such as switching frequency or specific noise frequencies. The result is a powerful stand-alone filter that has been verified both in simulation and in hardware. A number of papers have been published on these techniques. Present work involves applications of auto-tuning coupled inductor filters to distributed dc power systems.

Design of Small Inverter-Fed Induction Motors
P. T. Krein,* M. Amrhein
Grainger Center for Electric Machinery and Electromechanics

Conducted in the Everitt Laboratory

Nearly all induction machines built today are based on previous designs, carrying on constraints imposed long ago. Although new materials are employed, the basic concepts have not changed in decades. However, with power electronic inverters, some constraints no longer apply. This project investigates fundamental design choices, such as number of phases, operating frequency, and number of poles, as well as geometric parameters. The goal is to derive design rules to yield machines with improved efficiencies and operating characteristics.

Distributed Controls in a Distributed DC Power System
P. T. Krein,* R. Balog
National Science Foundation Grant, ECS-0224829

Distributed dc bus architectures have become the standard for power distribution in naval ships and telecomm applications. This study focused on distributed control techniques for point of load (POL) converters that act locally but in an orchestrated manner to ensure reliable system operation without a central controller. It is expected that information contained in the bus voltage can provide adequate information about the system state of health. To test these algorithms, a number of POL converters and controls were designed and built to create a distributed dc system.

Dynamic Simulations of Hybrid Electric Vehicles
P. T. Krein, * M. Amrhein
Grainger Center for Electric Machinery and Electromechanics; U.S. Department of Energy

Hybrid electric vehicle (HEV) simulators, used to design and analyze the performance of different components in hybrid cars, utilize steady-state models. However, in order to analyze designs in detail, dynamic simulations are necessary. Accurate information about peak and steady-state values of currents, voltages, and losses in power electronics devices can be obtained only from dynamic models. Other effects, such as rapid discharging of storage elements (batteries and capacitors), can be observed as well. The project goal was to develop a dynamic model of an HEV with various components, and to show that dynamic simulations could be used for the analysis of subsystem components, which would not be considered in a steady-state model. A dynamic HEV simulator based on Matlab-Simulink was developed at the University of Illinois several years ago and was modified to enhance and support new components such as fuel cells and ultracapacitors. The simulation concentrates on a series HEV, consisting of an energy source (fuel cell, combustion engine), an energy storage system (battery, ultracapacitor), and a traction system (transmission, induction machine, and inverter). The model accommodates the requirements of a design analysis, which especially includes losses in certain parts of the system. A journal paper was published in the IEEE Transaction on Vehicular Technology in May.

* Denotes principal investigator.
2005, featuring results obtained from the model. The paper showed that it is possible to efficiently simulate a dynamic HEV model and to gain valuable information about the dynamic performance of system and subsystem components.

**Flexible Digital PWM Control for Embedded Power Converters**  
P. T. Krein,* X. Geng  
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*University of Illinois, Motorola Center for Communications  
Conducted in the Everitt Laboratory

Switching power conversion for portable communications, personal digital assistants and most other electronic products is controlled through pulse width modulation (PWM). Since PWM produces strong components at the switching frequency and its multiples, one objective of X. Geng and P. Krein is to study spectral characteristics of PWM for purposes of noise and switching loss management. Nonrandom switching schemes are being developed to reduce interference without extra losses. Applications include flexible digital implementations for the full range of dc-dc converters and small motor drive units for automotive loads.

**Life Extension of Lithium-Ion Batteries**  
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Grainger Center for Electric Machinery and Electromechanics  
Conducted in the Everitt Laboratory

Limited battery life is a problem that affects industries such as aerospace, automotive, and portable electronics. Previously, life extension techniques such as equalization have been shown to increase the life of lead-acid batteries. In this work, experiments using battery equalization were run for over a year to observe changes in cell performance. Results showed that equalization improved pack utilization and extended life, even in small lithium-ion packs.

**Modeling of Sensorless Current Mode Voltage Regulator Modules**  
P. T. Krein,* J. Mossoba  
Grainger Center for Electric Machinery and Electromechanics  
Conducted in the Everitt Laboratory

Special power converters are needed to supply the low voltages required by recent microprocessors. These voltage regulator modules (VRMs), must provide fast regulation of output voltage, despite drastic changes in the current drawn by the CPU. The first step in successfully designing VRMs is to find a suitable mathematical model. The usual architecture involves numerous dc-dc converters acting in parallel. The research conducted shows suitable methods of simplifying models for VRMs. The proposed model achieves an acceptable level of detail without allowing the simplifications to compromise its accuracy. Optimization of these VRM systems is a subject of ongoing research.

**Modular Power Electronics Lab**  
P. T. Krein,* R. Balog, Z. Sorchini  
Grainger Center for Electric Machinery and Electromechanics

Power electronics is a subject taught best by laboratory work in conjunction with formal lecture. Flexible modules have been prepared that allow the students to quickly explore various fundamental topologies in dc to dc, dc to ac, ac to ac, and ac to dc converters without having to worry about the control or isolated gate drive support circuitry. An FET box consisting of two isolated devices and flexible controls allows numerous one- and two-switch topologies to be studied. An SCR control unit that supports controlled rectifier experiments has also been designed. Several undergraduate students assisted in the work.

**Re-Rating of Induction Machines for Traction Applications**  
P. T. Krein,* M. Amrhein, B. I. Fierro  
Grainger Center for Electric Machinery and Electromechanics

Electrical machines used in traction applications are often chosen such that their rated power matches the need. However, a machine is inherently designed for a certain torque. Higher output power can be achieved by spinning the motor faster at constant flux. By re-rating the stator winding of the machine to a low nominal voltage, the constant torque range can be extended to higher frequencies and speeds, thus increasing the output power. A 2.25 kW machine was re-rated by a factor of 2:1 and tested in three configurations. The efficiency increased with increasing frequency, provided the machine operated at constant torque.

**Software Development for a Modular Inverter**  
P. T. Krein,* P. L. Chapman,* G. Zhang, J. Wells  
Grainger Center for Electric Machinery and Electromechanics

A modular inverter is being created to serve as a test bed for various motor drive control schemes. This project is to

* Denotes principal investigator.
develop a software common platform for control algorithms. By integrating Matlab/Simulink, Code Composer Studio, and Spectrum Digital eZdsp, we are able to streamline software development from computer simulation to target implementation. The process is efficient and allows developers to focus on the control scheme. A user graphical interface allows real-time control of multiple parameters and data logging.

**Torque-Angle-Oriented Control for Induction Motors**
P. T. Krein,* G. Zhang
*Grainger Center for Electric Machinery and Electromechanics

*Conducted in the Everitt Laboratory*

Constant voltage-frequency-ratio control, field-oriented control, and direct torque control are the most popular ac motor control methods. There are also numerous techniques to improve the static and dynamic performance by applying more complex algorithms to these controls. The goal of a proposed torque-angle-oriented control is to simplify control algorithms so that reasonably good static and dynamic performance may be achieved without adding complexity to the motor control system. A digital algorithm has been developed and tested to show the advantages of the torque-angle approach.

**An Integrated 42-V Drive Design for Automobile Loads with a Low-Distortion Overmodulation Strategy**
P. T. Krein,* A. Kwasinski
*Grainger Center for Electric Machinery and Electromechanics*

The automotive industry is moving to higher voltages to support more electric automobiles. This study develops an integral design methodology that considers motors, inverters, and the electrical design as a complete system. The proposed design consists of an induction motor wound for a suitable voltage range and driven by an inverter. The inverter is used in an overmodulation regime when bus voltage is low. A 3-D representation of the modulation process showed that a signal based on triangle injection will minimize distortion. This approach was tested experimentally. It was demonstrated that dc bus utilization improves without added losses.

**A Microgrid-Based Telecom Power System Using Modular Multiple-Input Dc-Dc Converters**
P. T. Krein,* A. Kwasinski
*Grainger Center for Electric Machinery and Electromechanics*

A microgrid is an independently controlled portion of an electrical grid. It comprises its own power sources (such as fuel cells, solar cells, microturbines), energy storage devices (such as flywheels, batteries, ultracapacitors), and loads, usually interconnected with a larger grid. With independent control, a microgrid with a utility tie can deliver high reliability, high efficiency, and uninterruptible power functions, while reducing energy storage needs compared to traditional systems. This work explores a microgrid-based telecommunications power plant with a distributed architecture. Combinations of converters and controls create a flexible, reliable plant that meets performance needs of modern telecommunication systems.

**Dynamic Data Driven Applications for Power Systems**
P. W. Sauer*
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*National Science Foundation*

This project is investigating the use of time synchronized measured data for analyzing the state of power systems with particular emphasis on dynamic properties. The data are being considered for use in aiding power system operators in determining closeness to security boundaries, both static and dynamic.

**Integrated Security Analysis**
P. W. Sauer*
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*Department of Energy-CERTS*

*Conducted in the Everitt Laboratory*

This project is formulating new security analysis tools for operators using existing computational software code with online data. Traditional security application programs are used to create historical security results that will be used to develop learning algorithms. These algorithms will use both new computational results and historical results. This work is being done jointly with Washington State University.

**Reliability Tools for Power System Operators**
P. W. Sauer,* T. Overbye
*Department of Energy, Consortium for Electric Reliability Technology Solutions through Cornell University Power Systems Engineering Research Center*

*Conducted in the Everitt Laboratory*

This project is investigating advanced security analysis visualization concepts to enhance the reliability of the interconnected grid. Results from online security analysis will be presented and displayed to operators in a format suitable for rapid decision making and for assessing the acceptability of the system state.

* Denotes principal investigator.
Programming Languages, Formal Systems, and Software Engineering

Actor Coordination Abstractions, Semantics, and Implementation
G. Agha,* C. Varela
University of Illinois
Conducted in the Digital Computer Laboratory

This research focuses on the complexity of expressing interaction and coordination in Web-based computing. Researchers are working on providing high-level mechanisms to manage the complexity of scaling up computations over the Web, piggy-backing on the availability of Java byte-code for portability. The project defines several actor-based abstractions (casts, directors, messengers) to effectively harness the power of the World Wide Web as a global computing infrastructure. Groups of actors, or casts, represent an abstraction unit for naming, synchronization, migration, composition, and load balancing. Each cast contains a director, and intercast communication is performed via special actors named messengers.

Agent Generation and Control
G. Agha,* N. Jamali, P. Thati
U.S. Air Force Office of Scientific Research, F49620-97-1-0382
Conducted in the Digital Computer Laboratory

Agents provide a natural abstraction for using geographically distributed computational and memory resources. Agents are autonomous mobile actors that may be invoked to satisfy specific goals that may require traveling across physical and economic boundaries. Agents and agent ensembles can exhibit resource consumptive or otherwise unsafe behavior, raising security and resource management concerns. Agents must, therefore, be limited by the resources they consume in pursuing a goal. The project is developing concepts necessary to provide linguistic and system support for defining multiagent architectures. A related goal is to extend the mathematical theory of actors to allow reasoning about multiagent systems.

Customizable Coordination Services for Large-Scale Network Embedded Systems
G. Agha,* P. Chang, P. Thati, R. Ziaei
Defense Advanced Research Projects Agency, F49620-97-1-0382
Conducted in the Digital Computer Laboratory

The focus of this research is on developing application independent services to coordinate large scale network embedded systems. The coordination services will use customization and composition to enable dynamic adaptation in uncertain environments. The approach is to define algorithms that are based on stochastic models of system behavior, which enable the research team to represent the incompleteness in information about the current global system state as well as the unpredictability of the environment. The operational model uses probabilistic transitions rather than simple nondeterministic interleavings of actions, and it explicitly accounts for duration of transitions. The goal is to develop algorithms that provide for coordination in real-time and that guarantee the desired properties with sufficiently high probabilities. Examples include algorithms for approximate consensus (such as approximate synchrony), recovery, and hierarchical coordination. The algorithms will be implemented to provide a code basis for application independent coordination services. The implementation strategy is to build a repository of basic coordination services using reflective middleware. The goal will be to derive more complex algorithms based on simpler core resource management services.

Parametric Models for Large-Scale Agent Systems
G. Agha,* N. Jamali, P. Thati, R. Ziaei
Defense Advanced Research Projects Agency, F30602-00-2-0586
Conducted in the Digital Computer Laboratory

A goal of this research is to develop mathematical models to support the analysis and modeling of complex, large-scale agent systems. Instead of simple nondeterminism, the new theory will represent behavior stochastically. Moreover, instead of the current approach of using input-output behavior of individual agents, it will allow the behavior to be parametric in terms of variables that represent aggregated behavior of large numbers of agents. The operational model uses probabilistic transitions over an abstract representation of the current state of the system. The use of statistical techniques on this model for aggregating behaviors opens up the possibility of studying conditions under which either a stable equilibrium or chaotic behavior may occur. Another goal is to develop a
radically different logical framework for expressing properties of large-scale agent systems. The framework is inspired by Quantum Logics, which allow the expression of testable properties. This is in contrast to the usual algebraic approach that assumes every sentence (whether testable or not) can be assigned a truth value. Specifically, this research will enable macroscopic properties to be expressed without implying assertions about how they arise.

Software Architectures for Distributed Systems
G. Agha,* M. Astley
University of Illinois; National Science Foundation, CCR 9619522

Conducted in the Digital Computer Laboratory

The term middleware describes a set of services for integrating components of a distributed application, such as coordination and communication mechanisms. Recently, middleware services have been developed that support fault-tolerance, security, and other high-level policies. Such services have a fixed semantics, their implementation being influenced by the semantics of the application and the nature of the execution environment. The goal of this research is to provide a modular framework for developing middleware services. The project is formulating theoretical, linguistic, and run-time support for developing the needs of a particular application. Particular attention is paid to placement and mobility issues and vertical integration requirements.

Specifying and Deriving Mobile Systems
G. Agha,* P. Thati, R. Ziaei
U.S. Army, JHU 8812-48151

Conducted in the Digital Computer Laboratory

This research is focused on studying formal methods for specifying and verifying distributed software systems. The objective is to use automated deduction tools to reason about certain properties of mobile agents in open distributed systems. More specifically, security issues in authentication protocols and agent design are being studied. The project is formalizing an appropriate semantic framework that captures the fundamental properties of mobile computing and simplifies the task of reasoning. A specification language and logic will be developed based on the semantic framework. Finally, automated reasoning environments will be explored to find a suitable platform to implement the reasoning system.

Real-Time and Embedded Systems

Defect-Tolerant System Integration and Evolution
L. Sha*
U.S. Office of Naval Research, Sha 2063

Conducted in the Digital Computer Laboratory

Large software systems are developed by integrating software components. Unfortunately, many complex software components often contain defects. On the other hand, the technology exists to develop modest-size software components with a high degree of confidence. Flight control software is an example. This research focuses on algorithms and architectures that can leverage simple high-assurance components to ensure the integrity of large distributed real-time systems in spite of faults in complex software components.

Dependable and Secured Embedded Systems
L. Sha,* V. Adve, M. Spong
National Science Foundation, CNS 0209202

Conducted in the Digital Computer Laboratory

Faults and attacks during upgrades can be classified into three categories: application level control logic faults or attacks; code, data, thread, or process access faults or attacks; and resource depletion faults or attacks. To protect against them, our work will focus on integrated compiler static analysis and runtime checks to enforce the resource usage limits and to protect code, data, thread, and processes; and advanced safety controllers that can protect against coordinated control logic faults or attacks. Together with real-time scheduling technology, they form a foundation upon which applications can be upgraded without shutting down normal operation. Furthermore, the system stability can be maintained in spite of insider attacks masquerading as upgrades.

Quality of Surveillance and Control in Network Centric Warfare
L. Sha,* J. C. Hou,* M. Caccamo, W.-P. Chen, P. R. Kumar, R. Iyer, R. Zheng
Office of Naval Research, Multidisciplinary Research Program of University Research Initiative

Conducted in the Digital Computer Laboratory

In this project, we aim to develop a sound scientific foundation and technologies to allocate computing, sensing, and communication resources in a way that will enhance the quality of surveillance and control for the Department of Defense's vision of network centric cooperative engagement. We are working with the DoD

* Denotes principal investigator.
community to develop model problems that embody the fundamental scientific and engineering challenges faced by DoD systems, including network of multifunction radars, distributed sensor network, and advanced avionics systems. We are working to solve these model problems, demonstrate the solutions, and transition the technologies to major DoD programs through technology transition partners.

**Reliable and High-Performance Computing**

**Composable Processors**
N. P. Carter,* R. Gupta, G. Rasche, J. Stine  
*Defense Advanced Research Projects Agency, MARCO Center*

As silicon fabrication technology improves, processors and system-on-a-chip (SOC) designs are moving toward gridded layouts to minimize the impact of wire delays on performance. The composable processors project is studying techniques to reduce the design time and cost of grid-based custom processors through the use of a set of pre-designed "tiles" that can be composed together to form a variety of custom system architectures. In addition to the design of the tiles and systems that use them, we are developing software techniques to automatically generate high-performance, low-cost architectures for specific applications in this design methodology.

**Magnetoelectronic Reconfigurable Logic**
N. P. Carter*  
npcarter@uiuc.edu  
*U.S. Office of Naval Research, N00014-02-1-1038*

We are developing reconfigurable logic systems based on a novel magnetoelectronic device: the Hybrid Hall Effect device. These circuits can be configured to compute a wide range of logic functions with nonvolatile storage of their outputs and can be easily integrated into CMOS designs. Current challenges include reducing the power consumption of our circuits and developing system architectures that best take advantage of their capabilities.

**Self-Healing Reliable Reconfigurable Systems**
N. P. Carter*  
npcarter@uiuc.edu  
*University of Illinois*

Reconfigurable logic is an attractive fabric for reliable system design because faults in portions of the logic can be corrected by reconfiguring the system to avoid the faulty resources. We are developing design techniques for reliable systems implemented using reconfigurable logic. These techniques combine application-directed synthesis of redundant functionality to tolerate errors, run-time detection of faults, incremental synthesis for fast repair, and global resynthesis to avoid cumulative effects from multiple faults.

**The Amalgam Programmable-Reconfigurable Processor**
N. P. Carter*  
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*U.S. Office of Naval Research, N00014-01-1-0824*

Amalgam combines several conventional processors and blocks of reconfigurable architecture into a single microprocessor, using a clustered architecture to minimize the impact of wire delay on cycle time. Our results show that this architecture generates an average of greater than 12x speedup over a simple microprocessor on a range of benchmarks. We are currently developing compiler techniques for this architecture, as well as investigating architectural features to improve performance in far-future fabrication processes.

**Architectural Models for Highly Concurrent Instruction Execution**
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Superscalar processors can concurrently execute several instructions from a single thread, but are limited in the amount of concurrency they can find and exploit because they must fetch and rename instructions in program order. We build on compiler-assisted thread level parallelization mechanisms that concurrently fetch, rename, and execute multiple, widely separated, portions of the program. We are developing new dynamic techniques for using control-dependence information to find and exploit global instruction-level concurrency within a single thread of execution. Using these techniques, we can achieve execution rates four to ten times that achievable by superscalar processors.

**Advanced Predicate-Domain Code Optimization**
W.-M. Hwu,* J. W. Sias  
*Intel Corporation*

The predicated representation, in which control is implemented via conditional execution of instructions rather than branches, presents two general categories of new optimization opportunities: the optimization of program decision logic and the optimization of computation code using predication. This project aims to

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* Denotes principal investigator.
reduce control overhead by extracting control expressions from predicated code, optimizing these expressions using Boolean minimization techniques, and re-expressing control using more efficient sequences of predicate defining instructions. In the second area, this project works toward a paradigm in which stores, branches, and loop boundaries can be reordered freely to achieve performance goals.

**Architecture and Compiler Techniques for Optimizing Memory Accesses**

W.-M. Hwu,* H.-S. Kim, E. M. Nystrom
National Science Foundation, CCR 96-29948/98-09478; Intel Corporation

The goal of this research is to develop an integrated compiler and architecture approach to drastically reduce the frequency and cost of memory accesses in future computer systems. In particular, a compiler strategy that is built upon interprocedural pointer analysis and new heuristics for estimating the probability of colliding pointer contents will be developed to take full advantage of the data speculation features in future microprocessors. The insights provided by fully disambiguated memory accesses may drastically change the future course of run-time data speculation supports.

**Automatic Transformation of Traditional Software Components into a Data-Flow Execution Model**

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Due to the cost of building ever-larger uniprocessors with standard, single global on-chip storage, future gigascale computing platforms will increasingly rely on special-purpose hardware accelerators that employ decentralized data-flow computation models. However, the traditional von Neumann programming model will continue to be strongly preferred due to the high cost of changing the fundamental software model. To improve design productivity in the presence of the widening gap between the programming model and the underlying hardware platform, we are developing deep program analysis and transformation techniques that will enable tools to automatically extract data flow computation components from a von Neumann program.

**Compiler and Architecture Support for Program Tunneling**

Hewlett-Packard

Modern programming paradigms often impose major performance penalties on application programs. Object oriented programming, structured exception handling, automatic memory management, middleware services, and operating system calls are all examples of such costly features. The goal of this research is to eliminate the cost of these features for the frequently traversed paths of executable programs. Architecture support, in the form of new protection schemes and no-overhead profiling mechanisms, will be developed to enable the run-time optimizer to safely perform aggressive optimizations.

**Configurable On-Chip Memory Microarchitectures**

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Simple technology scaling offers little hope for breaking the difficult scalability and power/performance barriers associated with traditional on-chip memories. This project seeks to design new configurable on-chip SRAM microarchitectures that will enable large SRAM structures to approach the power efficiency of small custom memories for memory-intensive applications such as media and signal processing. The proposed structures support configurability in access ports, access latencies, and sleep-drowsy states. Our deep analysis toolset, a carefully engineered symbiosis of whole-program data flow, control flow, and pointer/data structure analyses, will disaggregate the application's memory data flows and will allow transformation of existing programs to take full advantage of the configurability of the new SRAM structures.

**Deep Program Analysis**

Intel Corporation; National Science Foundation, 98-09478

Current code analysis techniques draw dependences based largely on program structure and on register and memory accesses, many of which are not inherent to algorithms but are merely side effects of implementation in a particular architecture or coding paradigm. The conservative nature of these analysis techniques limits the compiler's ability to

* Denotes principal investigator.
perform broad, powerful code optimizations. Deep program analysis is intended to discern the fundamental algorithmic dependences of input programs from among those artificially imposed. The application of deep program analysis techniques could revolutionize program optimization, memory access microarchitecture, software development process, software verification, and software debugging.

**IMPACT Run-Time Optimization Framework**

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Advanced Micro Devices; Microsoft Corp.

Aggressive code specialization at compile time can achieve significant performance gains, although it is typically limited by risks of profile-dependence and code-explosion. Therefore, we are developing a framework for adaptive, runtime optimization, allowing profiling and specialization of code regions based on the current workload profile. Rather than solely focusing on opportunities in relatively unoptimized applications, this framework focuses on providing an efficient architecture for targeting optimization of opportunities presented by even the most aggressively optimized code. Components of these frameworks include efficient runtime optimization algorithms, techniques for identifying optimization candidates using nonintrusive profiling, and seamless deployment of optimized code.

**Java Run-Time Architecture**

W.-M. Hwu,* M. T. Conte, H.-S. Kim  
Hewlett-Packard

This project focuses on enhancements needed to create highly optimized native code for dynamic Java server applications. This includes the construction of a next-generation Java run-time prototype that offers a means of integration between dynamic code production and static code reuse. Also included are a streamlined object model, nonintrusive profiling, dynamic optimizations, reduced intermodule communication overhead, run-time deployment of optimized code, improved memory management subsystem, and hardware enhancements to support Java specific features.

**Memory-Efficient EPIC Processors**

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Semiconductor Research Corporation

Researchers are developing an improved EPIC architecture that will provide the high performance required by upcoming embedded applications while significantly reducing power consumption and memory bandwidth requirements. This architecture divides the processing resources of the chip into four independent clusters, with each cluster having its own program-controllable data memory. A decoded instruction buffer in each cluster reduces instruction fetch bandwidth and power consumption in loops. Compiler techniques are being developed to coordinate intercluster data movement to eliminate many of the memory accesses required during the execution of media programs on conventional architectures.

**Multipass EPIC Microarchitecture**

W.-M. Hwu,* R. D. Barnes, J. W. Sias, E. M. Nystrom,  
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Intel Corporation; Hewlett-Packard

It is well established that the in-order microarchitecture used by EPIC processor such as Itanium can exploit the compiler's proficiency in planning parallelism. However, the inability of this substrate to accommodate unexpected latencies, such as data cache misses, is its most vexing weakness. To address this problem, we propose multipass pipelining, a new class of in-order microarchitectures in which the processor pipeline defers execution of instructions with unready operands for later processing, thereby avoiding stalls. A first-generation design of this technique delivers substantial performance improvements for applications with significant memory stalls. Future generations promise to further enhance the performance while reducing complexity, area, and power.

**Next-Generation EPIC Compiler Technology**

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We have demonstrated that IMPACT's aggressive use of predication, speculation, and code replication in its structural transformation approach can attain substantial integer code performance increases over contemporary compilers for Itanium2. Challenges and opportunities remain: sophisticated combinations of transformations required to expose desired levels of instruction-level parallelism pose profile-dependence and stability issues. Selective specialization, while not yet controlled with great precision, shows an ability to improve instruction caching as well as ILP. Control and data speculation interact nontrivially with optimizations and operating system models. Finally, more sophisticated region selection and optimization techniques promise increasingly efficient use of wide EPIC resources.

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OpenIMPACT Compiler Release
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gelato; Hewlett-Packard; National Science Foundation,
CCR 98-09404
This project aims to release the IMPACT research compiler as a general-purpose, open-source compiler for the IA64 Linux platform. The research compiler's features, such as predicated compilation, instruction-level parallelism optimizations, compiler-engineered speculation, and profile-based optimizations, as well as its extensible research framework, will be retained. In addition, an easy-to-use interface will be provided that will allow OpenIMPACT to be used as a high-performance alternative to traditional compilers. This project will be released under the University of Illinois (UIUC/NCSA) Open Source License.

Predicate Analysis and Predicate-Aware Dataflow Analysis
W.-M. Hwu,* J. W. Sias
Intel Corporation
Efficient and accurate analysis of predicate relationships and predicate-aware dataflow analysis are essential to effective optimization and scheduling of predicated code. A predicate analysis engine must first quickly analyze the code at the function level to determine all relationships among predicates. Then, it must store its findings in a database that can accurately and efficiently answer queries about the relations among predicates. The first objective of this project is to create a function-level, accurate, and efficient predicate analysis engine. The second objective is to create a predicate-aware dataflow analysis engine that is both accurate and fast.

Rapid Customization of Systems Software
MARCO, Defense Advanced Research Projects Agency
(part of MARCO Center Soft Systems Thrust)
The objective of the project is to develop compiler-based, deep program analysis that transcends the boundaries currently separating the application, the dynamically linked libraries, and the operating system. Code-specialization of library functions and operating system services is based on interprocedural analysis of applications, programmatic logic analysis, data value analysis, and interthread escape analysis. Unnecessary code and modules are eliminated. A new fundamental model of the operating system functions, based on microkernel concepts, is developed to systematically verify the correctness of each customized version. Customization technologies are developed at the source and then at the binary level, with the long-term goal of handling commercial software. Potential benefits include rapid generation of software, smaller software footprints, reduced energy consumption, and higher performance.

Scalable Deep Program Analysis
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Future breakthroughs in computer architecture, software engineering, and trustworthy computing will rely on the compiler to perform program analyses that are considered infeasible today. Deep program analysis refers to compile-time techniques that can derive important properties of the program execution accurately. Examples of deep analysis include value ranges that can be assumed by variables, realizable data flow through memory objects, and memory locations that can be accessed by program components. New scalable approaches to deep program analysis are being developed to enable their application to large, complex software systems.

Scalable, Accurate Interprocedural Pointer Analysis
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Pointer analysis is a critical foundation for virtually all advanced program analysis techniques. In a programming language like C that supports an explicit address operator, indirect calls, structures, heap allocation, and pointer casting, memory activity can easily be obscured. We believe that highly accurate results and the ability to scale to large programs do not have to be mutually exclusive goals. To this end, a pointer analysis framework has been developed that provides an efficient representation for achieving accurate results through novel mechanisms to deal with procedural side effects, global variables, heap locations, and fields.
Ubiquitous Instruction-Level Parallelism Architectures
Intel; Motorola, Inc.; Microsoft Corp.; National Science Foundation, 98-09478

As instruction-level parallelism (ILP) architectures such as Intel IA-64 and TI C6x move into the mainstream of computing, it has become critical to solve the technical problems involved in making these architectures appropriate for future embedded applications. The goal of this research is to develop new compiler, architecture, and microarchitecture concepts to drastically reduce the code size, data transfers, energy consumption, and die size of future ILP processors. New techniques will also be developed to further enhance the performance of future ILP microprocessors.

Ultra-efficient Giga-scale Computing Platform Architecture
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This project seeks to achieve orders of magnitude of improvement in power efficiency in future computing platforms by systematically synthesizing and utilizing hardware accelerators in the forms of ASIP, ASIC, and FPGA. This approach is motivated by the availability of immense numbers of transistors in future chips and the limitation of activating only a tiny fraction of them at any given time. New system architectures allow seamless integration of accelerators with processors containing extremely high-bandwidth, short-latency communication. Advanced program analysis and transformation techniques convert traditional memory side-effect-based execution activities into explicit data flow, enabling extremely efficient direct hardware execution.

Value Analysis Compilation Framework
W.-M. Hwu,* J. W. Sias
Intel Corp.

Analyzing the flow of values through program computation provides many opportunities for improving the performance of computer systems. This project has two related objectives: the optimization of existing control flow through value analysis and value speculation. Value flow analysis facilitates dead code elimination and control optimization. Value speculation refers to the execution of instructions before all source operand values have been determined. This can be done when instructions generate the same value for each execution, the same value for a high percentage of executions, or predictable values. Compilers can exploit these regularities through code specializations, collectively referred to as value speculation.

Verification of Run-time Optimized Code
Hewlett-Packard

Executable programs are increasingly optimized and modified in the field. Just-in-time compilation of Java programs is a well-known example of such run-time code modification. The goal of this research is to overcome the technical challenges involved in automatic verification of run-time optimized code. An interdisciplinary approach that integrates program analysis algorithms and hardware test and verification techniques will be developed to cover a wide variety of software defects.

An Engineering Prototyping Environment for Compiling C Program Components into Application-Specific Logic
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This project seeks to establish an engineering prototyping environment to enable research in ultra-efficient gigascale computing platforms. In this environment, we are prototyping processor design, operating system support, compiler technology, synthesis paths, libraries, and device drivers needed in future heterogeneous software and logic systems. The first generation prototype is based on the Xilinx ML300 board, the Linux kernel, the Mentor Graphics ASAP tool chain, and the IMPACT compiler. The initial applications being prototyped are from the design driver applications of the MARCO Gigascale Systems Research Center with emphasis on future home entertainment applications.

Fault-Injection-Based Benchmarking
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In this research, we propose to explore issues and techniques for intrusion detection and intrusion tolerance in networked environments. Specifically, we will focus on
analyzing data on security attacks to determine vulnerabilities exploited by attackers and to classify the attacks according to their causes; generating measurement-based security attack models depicting the attack process; creating stochastic models that reflect behaviors of the system in the presence of variable workloads, errors, and security attacks; investigating measures and experimental procedures for benchmarking system reliability and security; understanding potential inconsistencies in application and system implementation; and proposing software and hardware intrusion detection and prevention techniques.

Gigascale Systems Research Center (GSRC): Reliable Systems Thrust
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Our focus is on designing hierarchical systems of hardware and software detection and recovery mechanisms to handle multiple and/or near coincident errors and to limit (or prevent) error propagation. We will explore a four-tiered approach to develop and integrate detection and recovery support at different levels of the system hierarchy. These levels can be classified as embedded programmable hardware support; operating system support; compiler support; and application support. Additional work will include updates to the ARMOR (adaptive reconfigurable mobile objects of reliability) software, NFTAPE, and the Reliability and Security Engine (RSE) project.

Processor Level Error Detection and Recovery Techniques
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Intel Research Council

This research is aimed at providing hardware-level, low-latency error detection and recovery. To achieve this goal we will develop and demonstrate hardware-implemented error detection and security mechanisms embedded as modules in the hardware-level framework, which is implemented as in integral part of a superscalar microprocessor. While the framework closely interacts with the processor pipeline, we do not propose to redesign the pipeline. Rather, the intent is to understand the pipeline to the extent needed for defining a robust interface with which we can demonstrate the operation and efficacy (coverage) of the modules. The framework and its interface with the pipeline are implemented in a reconfigurable portion of the die along with the processor. Example hardware modules we will explore include preemptive control-flow checking, a process health monitor, hardware-based checkpointing, and pointer-taintedness tracking.

Future Communication Technology for Public Safety
L. Liu,* J. P. Monks, W.-M. Hwu
Motorola, Inc.

In the next decade, the communications technology for public safety officials will be revamped to take advantage of the capability of modern digital communication systems. It is, however, unlikely that current commercial digital communication schemes will be able to satisfy the stringent requirement of constant connection, very low power, congestion control, and ease of use. The goal of this project is to define the architecture of the public safety digital communication systems via careful analysis of field requirements and creation of new communication protocols. An interdisciplinary approach is taken to integrate user behavior studies with core technology development.

Capacity Versus Robustness: A Tradeoff for Restoration in Mesh Networks
S. Lumetta,* S. Kim
Defense Advanced Research Projects Agency, MDA972-99-1-0005

Researchers are investigating capacity-efficient recovery methods in high-speed networks. The team recently demonstrated an extension of generalized loopback that operates on a subgraph of the full backup graph in an existing network. The backup capacity on remaining links can then be used to carry unprotected traffic, while all primary fibers retain failure protection. The results demonstrate robustness comparable or superior to that available with covers of rings while providing an additional unprotected traffic capacity of roughly 20% of the network's primary capacity.

Reliable, Efficient Communication on a Fast Ethernet Cluster
S. Lumetta,* J. Joh
University of Illinois, Campus Research Board

Networks of workstations (NOWs) have proven to be an inexpensive yet effective alternative to vendor-packaged parallel architectures. The performance of NOW's running on Fast Ethernet is often limited by TCP/IP communication overhead between the nodes in NOWs. Researchers are developing a new, lightweight, reliable communication protocol incorporating ideas of user-level communication,
lightweight flow control, and multiple network interfaces per connection. The protocol supports the large body of existing parallel applications written to the Message Passing Interface standard. Researchers will evaluate the effectiveness of their design in terms of the performance of these applications when using their protocol.

Survivability and Reliability in Direct Access Networks
S. Lumetta,* L. Li
Defense Advanced Research Projects Agency,
MDA972-99-1-0005

Researchers are developing routing and recovery protocols to provide reliable connectivity in direct access optical networks (DANs). DANs decouple access from routing, allowing new users to access the network without incurring the high cost of an optical switch. Through this decoupling, researchers enable more cost-effective and reliable network expansion. Direct access also simplifies the models of ownership by reducing the depth of the ownership hierarchy and the number of potential security hazards and points of failure for a connection. Finally, DANs allow network providers to offer a wider variety of bandwidth and reliability options.

An Adaptive, High-Performance Software Infrastructure for Hierarchical Systems
S. Lumetta*
National Science Foundation, CISE/ACIR Career Award

Machines with deep memories now dominate supercomputing and provide most enterprise-level computing, making the successful development of a general-purpose approach to such platforms imperative. Researchers are developing a high-performance infrastructure for these systems through the construction of four key components: a virtual machine that abstracts resource allocation and management issues into a simple interface; a hierarchy-aware run-time system that offers the illusion of a nonhierarchical system by adapting to the current hierarchical virtual machine; language constructs and dynamic compiler support to tune application behavior; and applications that demonstrate the value of the framework.

Creating an Integrated Modular Environment for the Modeling, Analysis, and Verification of Embedded Hybrid Systems
N. Neogi,* V. V. Lam, W. H. Sanders
National Science Foundation, CCR-0311616

We are creating a tightly integrated design, analysis, verification, and implementation environment for real-time, safety-critical embedded hybrid systems. Results will include a formalism-independent framework for embedded hybrid system architectural specification; efficient analysis and verification techniques that mitigate the state explosion problem by using escape paths and reward structures to create a directed search of the state space; and an integrated suite of stochastic modeling and analysis tools that augment the Möbius modeling tool with advanced techniques that solve scalable and complex hybrid models with respect to performance and dependability measures and capture the interactions typically found in embedded hybrid systems.

Immersive Network Simulation Testbed
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U.S. Department of Homeland Security

We are developing a network simulator for use in exercises by organizations interested in practicing their response to attacks on their IT infrastructure. The simulator uses high performance modeling and execution techniques, runs in real-time, and supports user interaction with simulated devices using emulation to provide a transparent veneer. A key goal is to use the simulator to automatically produce exercise "injects" that prompt players to react to simulated events.

Modeling and Analysis for Network Security Assessment
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Defense Advanced Research Projects Agency

We are developing simulation-based tools and technology to help a network analyst assess the impact of hypothetical attacks in a network, the effectiveness of defenses and countermeasures, and the quantified ability to continue operations in the face of a network attack. The result of our work will better enable network administrators and designers to protect their systems, and to quantify the cost, risk, and functionality tradeoffs inherent in network defense.

Survivable Trust for Critical Infrastructure
D. M. Nicol*
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National Science Foundation

We are exploring the design of a distributed trust backbone, based on computational nodes that provide hardened attestation for their hardware and software identities, organized as a peer-to-peer network. We are focusing on application of this technology to security applications in IT

* Denotes principal investigator.
management of critical infrastructure systems, such as SCADA.

**Measurement of Transient Errors in Microprocessors**
J. Patel,* K. Wells, H. Kommaraju  
*Jet Propulsion Laboratory*

This research addresses the measurement of error rates in commercial microprocessors. Microprocessors are core computing engines in the NASA Remote Exploration and Experimentation Project (REE). One serious problem is single-event upsets due to high intensity radiation in outer space. Knowledge of these error rates is essential in the design of the highly fault-tolerant REE computing systems. The measurement of these error rates is the focus of the proposed research. The research will generate software tools that are capable of measuring and characterizing any errors in microprocessors.

**VLSI Test**
J. Patel,* A. Pandey  
*Semiconductor Research Corp.*

The cost of test application of a single chip grows as a function of the number of clock cycles and/or number of storage bits required to test a chip. As a result, test application time and test data volume have become serious problems in testing of system-on-chip designs. In this research, new scan and BIST organizations are being devised that reduce not just data volume but also test time and associated hardware. Hybrid DFT techniques that combine BIST with deterministic scan vectors are also being investigated.

**CT-CS: Trustworthy Cyber Infrastructure for the Power Grid**
*National Science Foundation, #CNS-0524695*

The Trustworthy Cyber Infrastructure for the Power Grid (TCIP) NSF Cyber Trust Center was created to address the challenge of how to protect the nation’s power grid. It will significantly improve the way the power grid cyber infrastructure is built, making it more secure, reliable, and safe. TCIP is working to provide the fundamental science and technology needed to create an intelligent, adaptive power grid that can survive malicious adversaries, provide continuous delivery of power, and support dynamically varying trust requirements. We will do so by creating the necessary cyber building blocks and architecture, and by creating validation technology to quantify the amount of trust provided by the proposed approach.

**NGS: A Compiler-Enabled Model- and Measurement-Driven Adaptation Environment for Dependability and Performance**
*National Science Foundation, CNS-0406351*

Next-generation parallel and distributed computing must be dependable and have predictable performance in order to meet the requirements of increasingly complex scientific and commercial applications. This research will result in the production and distribution of a practical, integrated compiler and middleware system that uses online models and measurement techniques to achieve performance and dependability in a scalable manner under a wide variety of changing conditions. The techniques we develop could ultimately impact many diverse and critical applications, including those in the electric power distribution, aerospace, healthcare, and financial services sectors.

**U.S.-Germany Cooperative Research: Analysis of Multi-Paradigm Möbius Models Using Kronecker-Based Techniques**
W. H. Sanders,* P. Kemper  
*National Science Foundation, #INT-0233490*

This collaborative proposal between the University of Illinois and Dortmund University is working to make...
Efficient Algorithms for Temporal Planning under Nonlinear Constraints
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National Science Foundation, NSF 03-12084

This research involves the development of formal mathematical conditions for reducing the search space of planning problems and the demonstration of performance improvements in search engines of planner and other discrete searches. By formulating temporal planning problems as dynamic optimization problems with dynamic variables that evolve over time, this research finds new node-dominance conditions by developing the necessary and sufficient conditions for local optimality. By partitioning the search into stages and by finding only dominating states in each stage using the conditions developed, the search for feasible or optimal plans can be restricted to a much smaller subspace in each stage.

Loss Concealment for Real-Time Multimedia over IP Networks
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This research entails the design of effective multiple-description coding (MDC) algorithms at senders of IP networks, like the Internet, that take into account the reconstruction method used at receivers for concealing lost packets, in order to deliver audio and video data packets over these networks in real time with high quality (both subjectively as well as objectively). Loss concealment of compressed multimedia data is essential because many coding algorithms remove temporal differences in order to achieve high coding efficiency, thereby introducing a pervasive dependency structure into the bit stream. As a result, losses due to dropped packets or late arrivals will result in the loss of subsequent dependent frames, leading to audio or visual artifacts that can be long lasting and annoying. We have chosen MDC because it is effective for concealing losses in transmissions without explicit redundancy control and for networks without priority transmissions. Empirical tests on the Internet show that packet losses are bursty with small burst lengths. Statistics also shows that two descriptions in MDC are adequate in most situations, whereas four descriptions will allow us to control unrecoverable losses under 8% in the worst site measured. Our research results in efficient MDC algorithms that are input independent, without requiring run-time adaptation of the algorithms to new inputs.

Remote Sensing

High Latitude Mesospheric Dynamic and Chemistry Studies
G. R. Swenson,* A. Liu
National Science Foundation, ATM 99-0859

Studies of atmospheric gravity waves in the mesosphere and aurora will be performed with imaging and spectroscopy instrumentation at the NSF backscatter radar facility in Sondrestrom, Greenland. The measurement studies will be complemented by radar measurements as well as an all-sky imagery measurement provided by established instrumentation at the site. University of Illinois instrumentation includes a 4-channel photometer directed along the magnetic meridian, a CCD transmission imaging spectrometer, and a CCD all-sky airglow camera. Scientific objectives include the study of momentum and energy flux carried by propagating waves, chemistry associated with thin sporadic E and metal layers, and particle energy flux and beam characteristic energy of precipitating auroral particle beams. Image processing of 2-D spectrograms and 2-D images of atmospheric observations is a major activity with this program.

Imaging Studies of Mesospheric Gravity Waves
G. R. Swenson,* A. Liu
National Science Foundation, ATM 00-03180

Small-scale waves propagate from the lower atmospheric convection and mountain driven sources to the upper atmosphere. Existing chemiluminescence produces airglows, which are perturbed by the waves. Airglow imagers observe the perturbations and the horizontal wavelength, and amplitude of the waves are measured. The waves carry momentum and energy, which can interact with the large-scale dynamics to cause major dynamic effects. Observations have been made at Albuquerque, New Mexico, and currently at Maui, Hawaii, where the University of Illinois lidar makes complementary measurements. Signal processing is accomplished to extract the intrinsic wave parameters and power and spectral characteristics of the horizontal wave structure.

* Denotes principal investigator.
Technology Development for the MIDEX WAVES Satellite
G. R. Swenson,* C. S. Gardner
National Aeronautics and Space Administration, NAG5-8569

This program involves the development of technologies associated with a multiple sensor remote sensing satellite designed to measure small-scale waves in the middle and upper atmosphere. These studies include specifically the demonstration of infrared sensor array technology. Array sensors are planned for 1.26 and 1.45 microns that can be operated at elevated temperatures (160 K) but retain low noise attributes. This technology allows passive radiators rather than active refrigeration, enabling the sensors to operate with low power at a reliable, long lifetime on a small satellite. Other technologies include the development of remote sensing signatures from optical emissions as indicators of atmospheric dynamics for both the stratosphere and mesosphere. Instrumentation includes both nadir and limb imagers and spectrometers as well as a Michelson interferometer to measure Doppler winds.

Semiconductor Lasers

1065 and 1040 nm DBR Laser Diodes
J. J. Coleman*
HRL Laboratories

Conducted in the Micro and Nanotechnology Laboratory

Narrow linewidth, tunable semiconductor lasers are of interest to a variety of applications, including fiber optic communication systems, optical generation of microwave radiation, remote optical sensing, and molecular spectroscopy. Various configurations of tunable lasers have been analyzed, and a two- or three-section distributed feedback (DFB) or distributed Bragg reflector (DBR) laser is often the choice. The goal of these programs is to develop narrow linewidth, single longitudinal mode, strained layer InGaAs DBR laser diodes operating near 1065 and 1040 nm for remote sensing applications.

Development of Advanced Laser Diode Sources for Remote-Sensing Applications
J. J. Coleman, G. C. Papen*
National Aeronautics and Space Administration, NAG 1-1861

Conducted in the Micro and Nanotechnology Laboratory

Several outstanding technical issues for narrowband systems, such as water vapor DIAL lidars, must be resolved before solid-state, laser-based remote-sensing systems have widespread use. One issue is the development of cw local oscillators (LOs) based on semiconductor laser diode technology for use as injection seeders, which has not been fully realized because of the severe linewidth, tunability, and stability requirements of narrowband systems. This project will develop novel semiconductor devices specifically for use as tunable LO sources for narrowband water vapor DIAL systems operating in the 940 nm region. Researchers will focus on a novel ridge-waveguide, distributed-Bragg-reflector laser, which has significant performance improvements for optical remote-sensing applications relative to conventional Fabry-Perot or distributed-feedback lasers.

EOSS+ Laser Diode Substrate
J. J. Coleman*
Northrop Grumman Corp.

Conducted in the Micro and Nanotechnology Laboratory

The electro-optic test station known as the EOSS+ is designed to support the testing of laser platforms at 1.064 nm through the use of a laser diode source. The characteristics of this diode, such as center wavelength and peak power, are determined by the capabilities of the test receiver and the design of the EOSS+ unit itself. The purpose of this program is to provide for the fabrication of a custom-built diode grown from a novel substrate designed to meet specification.

High Brightness Laser Diodes
J. J. Coleman*
Nuvonyx, Inc.

Conducted in the Micro and Nanotechnology Laboratory

The objective of this program is to address several issues related to the MOCVD growth and characterization of InGaAs-GaAs strained layer lasers in the range of 920 nm to 1080 nm for high brightness applications. This approach will be to develop a real index guided laser with integrated beam expanders and other active and passive optics formed by selective area epitaxy. Present narrow stripe semiconductor lasers are generally limited to less than 200 mW of fundamental mode output power, because of the narrow aperture. If the beam can be expanded while retaining fundamental mode operation, then the operating power can be correspondingly increased.

* Denotes principal investigator.
Narrow Linewidth, Multiple Wavelength, Simultaneous-Emission Laser Diodes for Remote Optical Sensing and Other Applications
J. J. Coleman*
National Science Foundation, ECS 9900258
Conducted in the Micro and Nanotechnology Laboratory

The proposal describes a program to develop multiwavelength, simultaneous-emission lasers based on a ridge-waveguide distributed Bragg reflector semiconductor laser. The specific example of an application that defines the need of such lasers is the differential absorption, remote optical sensing of water vapor. A multiwavelength source with closely spaced narrow laser lines would be useful to obtain the detailed absorption profile without having to turn the laser on and off the absorption peak as is practiced currently. This program is designed to study and develop a simple multiple wavelength source suitable for these kinds of applications.

Semiconductor Laser Transmitters for Integrated Optical Interconnects
J. J. Coleman*
National Science Foundation, ECD 89-43166
Conducted in the Micro and Nanotechnology Laboratory

This program involves development of semiconductor lasers suitable for use in integrated optoelectronics. There are a number of key technical issues to be addressed in this program, including the development of etched facet structures, distributed feedback and distributed Bragg reflector grating structures, monolithic space division multiplexing arrays designed for fiber coupling, selective epitaxy for wavelength division multiplexing arrays and for multielement integration, master oscillator-power amplifier (MOPA) configurations, frequency stabilization, and distributed Bragg pulse shaper high-speed parallel-to-serial packet encoders.

Naturally Nanostructured Epitaxial Semiconductors
J. M. Gibson,* D. G. Cahill, J. E. Greene, A. M. Zangwill, J. J. Coleman
National Science Foundation, DMR 9705440
Conducted in the Micro and Nanotechnology Laboratory

This FRG/GOALI proposal addresses basic materials science and engineering issues in a collaborative program between the University of Illinois and Hewlett-Packard Laboratories to understand fundamental phenomena and interactions associated with naturally nanostructured epitaxial semiconductors. Goals of the project are to obtain semiconductor epitaxial nanostructures smaller than feasible via lithography and to examine their applications to novel devices. Strain-induced self-organization and kinetically driven pattern formation are two approaches being taken to achieve naturally nanostructured materials.

Semiconductor Physics

Heterojunctions, Transport, Ion Implantation, and Defects in III-V Semiconductors
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U.S. Office of Naval Research, N00014-89-J-1470
Conducted in the Beckman Institute for Advanced Science and Technology

The nanostructure related research is focused on electronic properties of carbon nanotubes. We are particularly interested in metal-semiconductor transitions of these tubes due to a perturbation of the symmetry. We have shown that this transition can give rise to transistor function (a metallic field effect transistor). Work on topics in quantum information, particularly the Theorem of Bell, is also in progress.

High Field Transport of Free Carriers at Interfaces
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U.S. Army Research Office, DAAL03-86-K-0099
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In this research, we are studying the ultimate limitations of electronic transport in silicon and III-V compounds, including superlattices and the corresponding potential for new devices, as well as the advantages of including heterolayers in conventional devices. The theoretical approach includes Monte Carlo simulations and explicit solutions of the Boltzmann equation. We are also developing a new algorithm to solve problems of quantum transport.

Monte Carlo to the Limits of MOS Scalability
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The goal of this research is to develop 3-D full-band Monte Carlo simulation software for the analysis of nanoscale MOS structures. Devices investigated include double-gate MOSFET and FinFET. An original quantum correction

* Denotes principal investigator.
scheme has been developed to include size quantization
effects in the semiclassical Monte Carlo procedure.
Comparisons are carried out with quantum simulation
approaches based on nonequilibrium Green's function
formalism.

**Network of Computational Nanotechnology**
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* Denotes principal investigator.

**Conducted in the Beckman Institute for Advanced Science and Technology**

This work is part of a Multi-University National Science
Foundation Center. The main goal of our work is the
simulation of tubular nanostructures. We investigate both
nanostructures of biology, such as biological ion channels,
as well as nanostructures related to solid state electronics,
such as carbon nanotubes. The tools of the investigation
are based on and developed by methods of computational
electronics (e.g. Monte Carlo simulations).

**3-D Self-Consistent Simulation of Quantum Dot Spin Transistors of Quantum Information Processing**
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**Semiconductor Research Corporation, 2003-NJ-1045**

**Conducted in the Beckman Institute for Advanced Science and Technology**

This research concentrates on developing 3-D self-
consistent computer tools for realistic simulation of spin
operation in silicon quantum dot spin effects transistors in
order to assess their feasibility and viability for
applications in quantum information processing. We
consider Si FET-device configurations similar to Kane's
proposal to achieve a C-NOT gate. Our purpose is to obtain
a coherent 3-D picture of the interdependence among
physical parameters and device considerations for spin-
qubit operations, and to provide design rules for optimizing
the device.

**Scalable Spin-Qubit Circuits with Quantum Dots**
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**Defense Advanced Research Projects Agency, QuIST
program, DAAD19-01-1-0659**

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This research is aimed at achieving a scalable elementary
spin-qubit circuit for quantum computing that is based on
the manipulation of electron spins in coupled III-V
semiconductor quantum dots (QDs). We take advantage of
the advanced technology for planar and lateral QDs
AlGAs/GaAs heterostructures and the fact that the electron
effective mass is small, which eases the conditions for
quantum confinement. Moreover, III-V materials enjoy
long spin coherence times, which is of utmost importance
for preserving quantum information over many qubit
operations. For this purpose, we have assembled an
international research team involving the University of
Basel, the University of Delft, Harvard University,
Princeton University, and Tokyo University. Team
members have complementary expertise in the physics of
quantum computation and spintronics in nanostructures.
These areas of expertise are fully integrated into a coherent
and interactive effort, leading to the realization of an
elementary qubit circuit.

**Interactive Tools for Nanotechnology Education**
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**NSF National Science Center for Learning and Teaching
Nanoscale Science and Engineering**

This project involves a multidisciplinary, multi-university
team involving Northwestern University (lead institution),
University of Illinois at Chicago, University of Illinois at
Urbana-Champaign, Purdue University, and University of
Michigan. One of the goals is to pursue research in
education addressing the introduction of nanotechnology
concepts at various school levels, from middle school to
undergraduate programs. Our group is developing
interactive simulation and visualization tools to explore
new ways to introduce advanced concepts in the curricula.

**Simulation of Charge Transport in Ionic Channels**
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**NSF Network for Computational Nanotechnology**

**Conducted in the Beckman Institute for Advanced Science and Technology**

The well developed tools of computational electronics
have been adapted to simulate ion transport in biological
channels, treated as nanoscale natural devices. Continuum
(drift-diffusion) and particle (Trasport Monte Carlo)
simulation approaches have been developed where
interaction with the aqueous environment is resolved in
terms of mobility or scattering rate. The goal of this work
is to provide a scalable input-output description of natural
nanopores for uses in bioelectronic sensor design.
Artificial or biomimetic nanopores are also investigated

* Denotes principal investigator.
with similar simulation tools, for the design of artificial membranes incorporating features of biological ones.

**Simulation of Nanoscale Biological and Biomimetic Systems**

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Simulation of ion charge transport in membranes is studied using various engineering simulation approaches, including continuum and particle models, to develop design methodologies for nanoscale systems. Physical approaches like classical and quantum molecular dynamics are relied on to provide first-principle calibration of transport parameter for the engineering reduced order models. The goal of this multidisciplinary project is to create a software infrastructure to support the future design of biomimetic components for a variety of applications in nanomedicine, including implantable self-sustaining power sources and artificial organs.

**The Science and Technology of Nano/Molecular Electronics: Theory, Simulation, and Experimental Characterization**

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Conducted in the Beckman Institute for Advanced Science and Technology

This project is part of a DURINT multi-university effort, with Stevens Institute of Technology as lead institution. The specific goals of this subcontract are to develop nanelectronics simulation tools to understand the ultimate limits of silicon technology and explore new device concepts based on quantum effects. The emphasis of the work is on 3-D simulation and high performance parallel computing, using nonequilibrium Green's function and Monte Carlo simulation approaches.

**Semiconductors**

**Ge-Sb-Te Phase Change Materials: Optical and Electronic Properties, Structural Transformations, and Fabrication of Nanostructures**

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* National Science Foundation, DMR-0412939

Conducted in the Micro and Nanotechnology Laboratory

The properties of Ge-Sb-Te alloys and the rapid amorphous-crystalline phase change that they exhibit are being investigated using ellipsometry, optical absorption and reflection spectroscopy, photoconductivity, photoluminescence, electrical conductivity, Hall effect, high resolution TEM, and fluctuation electron microscopy. Specific problems include: optical, electronic, and structural characterization of sputtered thin films of the materials; the effects of composition, conditions of synthesis, thermal annealing, and optical or e-beam irradiation on their properties; detection and characterization of nano-crystallites in the amorphous phase and their role in the phase change mechanism; the spatial limits/resolution of the phase change, aimed at fabricating quantum structures.

**Photoluminescence Studies of Semiconductor Nanostructures and Rare Earth-doped Semiconductor Materials**

S. G. Bishop,* I. Adesida, J. J. Coleman, J. O. White

University of Illinois

Conducted in the Micro and Nanotechnology Laboratory

This research program applies photoluminescence (PL), photoluminescence excitation spectroscopy, time resolved PL, and PL imaging to the characterization of defects and impurities in bulk and epitaxial semiconductor materials, and the composition, doping, thickness, interfaces, uniformity, and quantum confinement effects in semiconductor nanostructures. Rare earth-doped semiconducting glasses and rare earth implanted GaN are being developed as sources of near- and mid-IR radiation. Excitation of the intra-4f shell emission from rare earth dopants (e.g. Er$^{3+}$, Pr$^{3+}$, Dy$^{3+}$) in chalcogenide glasses by broad band optical absorption in the Urbach edge of the host glass is under investigation as a novel optical pumping mechanism.

* Denotes principal investigator.
High Quantum Efficiency Infrared Photodetector Arrays Based on Nanowire Heterostructures

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National Reconnaissance Office, NRC000-05-C-0023

Conducted in the Micro and Nanotechnology Laboratory

The goal of this project is to develop high quantum-efficiency, high color-contrast multi-wavelength quantum wire infrared photodetector (QWRIP) arrays. The QWRIP uses a self-assembly approach to create high-density nanoscale quantum wire structures that provide the basis for high quantum efficiency infrared detection. The QWRIP combines the best features of the quantum well infrared photodetector (QWIP) and quantum dot infrared photodetector (QDIP) to offer normal incidence absorption, high quantum efficiency, and adjustable infrared absorption from 8 to 40 μm. Unique polarization sensitive absorption properties of quantum wires enable two distinct quantum wire infrared detection layers (or a quantum wire layer and a quantum well layer) with different spectral responses to be monolithically integrated without interference, yielding excellent color contrast.

Center of Hyper-Uniform Nanophotonic Technologies for Ultra-Fast Optoelectronic Systems (HUNT Center)

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The mission of the HUNT Center (Center of Hyper-Uniform Nanophotonic Technologies for Ultra-Fast Optoelectronic Systems) is the development of critical technologies, including hyper-uniform nano-photonic fabrication, high performance quantum dot vertical-cavity surface-emitting lasers, and ultra-fast light-emitting transistor-based lasers for the realization of ultra-fast (≥100Gb/s) optoelectronic interconnect systems. Center programs encompass semiconductor nanoscale materials growth, nano-patternning, nanoscale material analysis, nanostructure laser device design and fabrication, optical receiver design and fabrication, as well as high-speed optoelectronics integrated heterogeneously on a common semiconductor platform to perform ultra-fast optical interface functions.

GaAs-based Metal-Oxide-Semiconductor Structures

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The goal of this research program is to develop oxide deposition techniques for the fabrication of GaAs-based metal-oxide-semiconductor field effect transistors (MOSFETs). Various oxides, including SiO$_2$, Al$_2$O$_3$, Ga$_2$O$_3$, and Gd$_3$Ga$_5$O$_{12}$ are deposited on GaAs in an ultrahigh vacuum system at Bell Laboratories to form MOS structures. Researchers will characterize their structural, optical, and chemical properties through transmission electron microscopy, photoluminescence spectroscopy, and Auger electron spectroscopy, respectively, to improve the oxide deposition process.

Ultra-High-Speed Heterojunction Bipolar Transistors

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Conducted in the Micro and Nanotechnology Laboratory

The goal of this research is to develop viable techniques that allow demonstration of Inp-based HBTs with fT>400GHz for insertion into the ultra-high-speed (>100 GHz) circuits.

VCSEL and Smart Pixel Research for VLSI Photonic Systems

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The purpose of this research is to develop technology related to VLSI photonic systems. The scope of the program ranges from basic materials research, to the fabrication of large-scale integrated circuits, to advanced technologies for the integration of systems in heterogeneous materials. Goals of the project include the design, growth, fabrication, and testing of III-V semiconductor vertical cavity surface-emitting lasers; the development of smart pixels, circuits for the detection of optical signals, intelligent routing of the information, and re-emission of optical signals; and the development of techniques for the integration of heterogeneous materials.

* Denotes principal investigator.
Surface Engineering for Compliant Epitaxy
K. C. Hsieh,* K.-Y. Cheng,* I. Adesida
Defense Advanced Research Projects Agency, F49620-98-1-0496

Conducted in the Micro and Nanotechnology Laboratory

The goal of this research is to realize dislocation-free and stress-relaxed lattice mismatched epitaxial growth of different compound semiconductors on various substrates across the whole wafer or on selected areas for device integration applications. Our immediate goals include fundamental understanding of the growth conditions related to the formation of strained-modulated and defect-absorbing templates and the development of techniques to fully control the formation of strain-absorbing and deformable growth templates with an emphasis on processing simplicity and system integrability. InP-based optoelectronic and microwave devices will be integrated selectively on surface-engineered GaAs substrates.

Wafer Bonding for Advanced Optoelectronic Devices
K. C. Hsieh,* K.-Y. Cheng
Defense Advanced Research Projects Agency, MDA 972-00-1-0020

Conducted in the Micro and Nanotechnology Laboratory

The goal of this research is to develop wafer-bonding technologies for hybrid integrating mismatched device structures for advanced optoelectronic integrated circuits. The potential applications include fabricating high-performance visible LEDs, vertical-cavity-surface-emitting lasers, resonant-cavity photodetectors, 2-D and 3-D photonic crystals, and high-performance semi-insulating wafer substrates. Our current efforts are focused on developing high-efficient wafer-bonding strategy and fundamental understanding of the hybrid interface properties, including interface microstructures, electrical and optical characteristics, interface strain/stress and adhesion properties, and so forth. The long-term goals will include developing chip-scale photonic/electronic integration methodologies for high-density 3-D architectures.

ITR/SY: Foundations of Solid-State Quantum Information Processing
National Science Foundation, EIA-01-21568

The core of this program is an exploration of three distinct but related solid state technologies as candidates for quantum information processing: single spins on individual P-donors in silicon, ferromagnetic particles in close proximity to a superconductor, and superconductor phase electronics based on Josephson tunneling and SQUIDs. Supporting this effort will be a theory component that addresses key issues concerning the evolution and monitoring of quantum-entangled states and an experimental study of qubit dynamics using the highly developed techniques of modern quantum optics.

Biologically Inspired Artificial Haircell Sensors
C. Liu,* D. L. Jones, F. Delcomyn
U.S. Air Force Office of Scientific Research, F49620-01-1-0496

Conducted in the Micro and Nanotechnology Laboratory

This work is aimed at developing artificial haircell sensors that are inspired by biological haircell sensors. This work is focused on studying the fundamental principles of neurological responses of haircells to develop micromachined devices that mimic the performance of biological entities.

CAD Design Tools for Millimeter-Wave Wireless Communication Microsystems
C. Liu,* M. Feng, S. M. Kang, E. Michielssen, J. Schutt-Ainé
Defense Advanced Research Projects Agency, Composite-CAD Program, F30602-97-0328

Conducted in the Micro and Nanotechnology Laboratory

A mixed technology computer-aided design system is being developed for the cost effective design of wireless communication modules that will ultimately enable networked distributed MEMS. The module, operating at millimeter-wave frequencies, will allow direct interface between MEMS transducers and the free-space electromagnetic radiation. MEMS components offer unique advantages for RF circuits. As an example, micromechanical switches exhibit lower insertion loss and higher isolation compared with conventional electronics switching components. MEMS fabrication technology for silicon and composed semiconductor materials is being studied in order to realize mechanical RF switches as well as high-gain antennas to validate results of the E-M simulation.

Integrated Sensitive Skin with Advanced Data Architecture
C. Liu,* N. Shanbhag, D. L. Jones
National Science Foundation, IIS 00-80639

Conducted in the Micro and Nanotechnology Laboratory

An interdisciplinary team of researchers will develop microfabricated, multiple modality sensor skin with
advanced data structure and signal processing algorithms. A flexible sensor skin that imitates biological tactile sensors faces important challenges in terms of microfabrication, materials, density of sensors, and accompanying circuits. Prof. Liu and students will develop advanced multimodal sensors with self-configuration capabilities. Prof. Shanbhag is developing energy efficient signal processors, while Prof. Jones is interested in developing signal processing algorithms that are biologically inspired.

Controlled Coupling of Donor Atom Wavefunctions in Silicon
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U.S. Army Research Office, DAAD 19-00-1-0407
The goal of this project is to selectively place PH₃ molecules onto the hydrogen-terminated silicon surface via STM lithography and overgrow them into the crystal as phosphorous donors. If successful, this work could provide a means for constructing quantum computers based on control of ground-state wavefunctions on individual P-atom donors. Other potential applications include single-charge electronics, cellular automata, and nanometer-scale field-effect transistors. Reproducible characteristics are made possible by the large ~5nm Bohr diameter for individual donor bound states, so that coupling between nearest neighbors will be defined accurately if redistribution is limited to ~1nm or less during ultra-low-temperature overgrowth.

Wavefunction Engineering of Individual Donors for Si-Based Quantum Computers
J. Tucker,* M. Feng, Y. C. Chang, T. C. Shen (Utah State Univ.), R. R. Du (Univ. of Utah)
U.S. Army Research Office, 42257-PH-QC
The goal of this multi-investigator program is to develop the basic fabrication and measurement technologies needed to implement a silicon-based quantum computer. To do this, researchers must place individual phosphorous donors into the silicon lattice with atomic precision, establish electrical control over wavefunction overlap between donor-pairs, and successfully detect spin states of the resulting two-electron system by measuring the presence or absence of electronically-induced polarization. The research team does not propose working quantum logic gates within this three-year project. If successful, however, that goal will be undertaken in a follow-up program that incorporates SiGe overgrowth and patterning of individual top-gates for each P-atom donor.

Signal and Image Processing

Directional Multiresolution Image Processing: Theory, Algorithms, and Applications
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National Science Foundation (CAREER Award)
This project seeks to develop new "true" two-dimensional representations that can deal more effectively with typical images having smooth contours. The focus is on the development of directional and multiresolution image expansions using nonseparable filter banks, in much the same way that wavelets were constructed from filter banks. In essence, the proposed research pursues nonseparable extensions of wavelets and multiresolution techniques so that they can capture the directional information—an important and unique feature of multidimensional signals. In parallel, newly developed image representations will be explored in a variety of applications, where substantial improvements over current methods are expected.

A Modern Autofocus Methodology with Applications to Radar Imaging
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National Science Foundation
Synthetic aperture radar (SAR), geophysical and seismic imaging, ultrasound imaging, optical coherence tomography (OCT), and many forms of astronomical imaging are examples of coherent imaging systems. In practice, due to imprecise knowledge of the motion of the sensor or due to signal propagation through a medium having a spatially varying propagation velocity, the produced imagery is improperly focused. This project develops a modern autofocus methodology that provide a systematic approach to the design of autofocus algorithms. Toward this end, a theoretical paradigm is devised for the autofocus problem in which prior assumptions in the problem statement are systematically utilized in producing efficient, high-quality image restorations.

Audiovisual Speech Recognition in Automotive Environment
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Speech recognition in an automobile is typically performed using a single microphone, often mounted in the sun-visor

* Denotes principal investigator.
in front of the driver. With typical road noise, most recognizers generate too many errors for practical use. This research project experiments with speech recognition using multimodal recordings acquired by a visor-mounted array including eight microphones and four cameras. We focus on accurate visual face tracking lip feature extraction and robust audio noise cancellation. Our goal is to demonstrate that error rate of a multichannel audiovisual recognizer is much lower than error rate of a standard recognizer under automotive test conditions.

**Landmark-based Speech Recognition in Music and Speech Backgrounds**

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National Science Foundation, CISE 0132900

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Human listeners are able to recognize speech based on dynamic portions of the signal, even if all static portions are masked by noise or by background music. This research seeks to develop mathematical models capable of abstracting the perceptual response patterns of human listeners. Probabilistic auditory scene analysis uses cognitive stochastic automaton models, combined with use of dynamic Bayesian network methods, in order to imitate the ability of listeners to understand speech mixed with loud background music. Landmark-based speech recognition imitates the extra sensitivity of humans to dynamic as opposed to static signals.

**Prosodic, Intonational, and Voice Quality Correlates of Disfluency**

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Prosody is the stress and rhythm pattern of naturally spoken language. Linguists agree that the sound of a phoneme depends on its prosodic context, but experimental data describing the prosodic-phonemic interaction are only now becoming precise enough to support efforts in automatic speech recognition. Our research seeks to precisely describe the prosodic-phonemic interaction using both detailed phonetic analysis and probabilistic speech recognition models. This research has already succeeded in demonstrating, for the first time in the literature, that the use of prosody can lead to improved word recognition accuracy in a large-vocabulary speech recognition experiment.

**Face Processing**

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Researchers are developing methodologies and algorithms for 2-D and 3-D face analysis with applications in face detection, recognition, tracking, and animation. For analysis, we are particularly interested in outdoor scenarios where the illumination and head pose are highly varying. For animation, a major project is text- and speech-driven realistic synthetic talking faces.

**Image and Video Databases**

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Conducted in the Coordinated Science Laboratory and the Beckman Institute for Advanced Science and Technology

A number of challenging issues in image and video indexing and retrieval are being studied. Of particular interest are the following: similarity- and example-based retrieval, the use of relevance feedback from users to improve retrieval performance, and the recognition of semantic concepts in video based on multimodal cues.

**Multimodal Human–Computer Interaction**

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National Science Foundation, IIS 00-85980, IIS 01-38965, and CCF 04-26627

Conducted in the Coordinated Science Laboratory and the Beckman Institute for Advanced Science and Technology

The term "human-computer interaction" is used in a broad sense to include communication between persons and computers as well as communication between persons mediated by computers. Researchers are investigating a variety of issues related to the use of computer vision and image processing in HCI, as well as the integration of vision, audio, and speech. Examples include visual human (body, face, hand) tracking and analysis, combining speech and visual hand tracking in manipulating virtual objects, audio-visual speech recognition in noisy environments, and audio-visual human emotion recognition.

* Denotes principal investigator.
Video Analysis
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ARDA MDA 904-03-C-1787

Research conducted at the Coordinated Science Laboratory and Beckman Institute for Advanced Science and Technology

Researchers are using generative probabilistic models (GPM) to do video analysis. Tasks include stabilization, denoising, superresolution, segmenting video into layers, and video event retrieval based on examples. Applications include online surveillance and monitoring, and offline analysis using video archives.

Remote Reality: 4-D Audio-Visual Reconstruction and Compression from Multiple Sensors
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National Science Foundation (ITR Grant)

This project develops new signal processing techniques for reconstruction of the audio and visual recording at an arbitrary location in space and time from multiple acoustic and video sensors, but extending recent research in adaptive beamforming, multisensor signal processing of nonstationary signals, and fundamental new advances in multidimensional signal representation. Practical four-dimensional audiovisual recording, transmission, playback, and remote reality will be demonstrated with low-cost, conventional sensors attached to networked computers, thus confirming the practicality of the proposed methods and applications.

A Comprehensive Retargetable Embedded Systems Software Development Environment
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University of Virginia, National Science Foundation subcontract

New compiler technology and a high-performance software development environment specialized for digital signal processors are being developed. Challenging signal processing applications in wireless video communication will be used as a testbed for evaluating the performance of the new optimizing compiler technology. The new compilation and software tools will be introduced into an instructional Digital Signal Processing Laboratory course for leading-edge undergraduate education and additional evaluation.

Soft Materials
Polymer Studies in Thin-Film Microelectronics
ACS-PRF, 37027-AC7

Polymer material is used extensively in microelectronics including nm thick resists (photoresist) for image patterning and self-assembled monolayers (SAMs) thin coating for microelectronics. It can also be used as an active component in terabit/in² storage devices such as the millipede where the thermal (at ultrafast heating rates) properties of nanometer thick polymers (e.g., polystyrene and PMMA) are of critical importance. We use a recently developed MEMS device, the nanocalorimeter, to study the thickness dependence of glass transition temperature in ultrathin polymer films. This new technique is 1000 times more sensitive than conventional DSC systems. Our preliminary results show that it has the capability to measure polymer films with thickness of only 1.5 nm.

Supercomputing Research and Development
An Integrated Framework for Performance Engineering and Resource-Aware Compilation
National Science Foundation, EIA 99-75019

This project developed a comprehensive and integrated approach to application composition and development, system and application modeling and evaluation, performance characterization, compiler optimization, and low-overhead runtime support. Achieving these capabilities required fundamental advances in methods for hierarchical, multilanguage modeling, simulation, and evaluation, and techniques for adaptive, resource-aware compilation and runtime support. We took a systematic and synergetic approach to making these advances and

* Denotes principal investigator.
incorporated them into an integrated performance engineering framework and resource-aware compilation and runtime system. In addition, we demonstrated the use of the integrated framework/system via application to several important parallel and distributed multimedia, video database, and computer vision applications.

Surfaces and Interfaces

Synthesis and Characterization of Nanostructured Alloys with Enhanced Mechanical Properties
P. Bellon,* J. R. Abelson,* S. Jayaraman, A. Chaterjee
National Science Foundation, DMR 0354060-; CECM-Vitry (CNRS France)

This collaboration is to carry out synthesis and characterization of nanostructured diborides of zirconium, titanium, and chromium for super-hard coatings with low friction coefficients and low wear rates. The following areas are investigated: novel synthesis techniques, in particular by CVD of mixed phase materials; characterization of structure and defects in amorphous and nanocrystalline films through advanced TEM techniques; and analysis of the friction and wear behavior using the driven systems approach as a theoretical framework. Our goal is to produce an improved understanding of how microstructure varies with stoichiometry, with transition metals, CVD conditions, and wear parameters.

Systems and Control

Efficient Resource Management for Controlled-Mobility Wireless Networks
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National Science Foundation, Information Technology Research Program, CCR-0325716

Today’s embedded computers are increasingly mobile and ubiquitous, are capable of interacting with the environment, and can communicate with one another over possibly vast and pervasive networks. Mobile wireless networks are envisaged to revolutionize the way people and organizations will interact and communicate. While most of the wireless networks are not expected to be capable of controlling their own motion, new technological possibilities are emerging to provide small embedded devices with the means to propel themselves, with an energy expenditure that is comparable to the energy budget of communication and computation. Since the power required for propulsion typically decreases with the mass of the device, cheap mobility has the potential to dramatically impact the way networks of small, “smart” devices are designed and operated. We will call a network of embedded devices endowed with computation, communication, and motion capabilities a controlled-mobility wireless network. The purpose of this project, and its intellectual merit, are to be found in the development of a new conceptual framework for the design, development, and operation of efficient and reliable networks with such characteristics.

Creating An Integrated Modular Environment for the Modeling, Analysis and Verification of Embedded Hybrid Systems
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National Science Foundation, CCR-0311616

This project involves the development of an integrated modeling environment for the fast simulation and verification of systems that have both continuous and discrete components, such as air traffic control systems and biological systems. The modeling environment uses an abstract functional interface to allow a wide variety of modeling formalisms and solvers to be incorporated and leveraged throughout the simulation and verification process.

Fast Simulation of Hybrid Biological Systems
B. Sanders,* N. Neogi
neogi@uiuc.edu
Pioneer Corporation

This project investigates techniques for the fast simulation of large discrete event systems that are prevalent in biological models. The research leverages hybrid modeling techniques that allow for the approximation of discrete interactions by continuous differential equations. Examples of current relevance, such as the biological toggle switch, are currently being studied.

Control of Spatio-Temporal Systems
P. G. Voulgaris,* B. Bamieh
petros@decision.csl.uiuc.edu
National Science Foundation

Many modern applications of controlling distributed systems pose spatial invariance. A typical example is a symmetric array of micromechanical systems, where many such devices are located according to some usually symmetric pattern. Using suitable extensions of the one-dimensional results, one can design optimal and robust
controllers. However, the resulting control algorithms are, in general, centralized and impractical to implement. To alleviate this difficulty, a degree of decentralization is imposed on the controller, and algorithms are developed to optimize performance under such information-limiting constraints. The approach resorts to convex formulations of the underlying optimization.

**Distributed Control for Large Telescopic Systems**
P. G. Voulgaris,* S. Jiang, L. Thompson, N. Holloway
petros@decision.csl.uiuc.edu
*University of Illinois*

In this project we study and develop distributed control methods for the primary mirror of large segmented telescopes. The aim is to determine the limits of imaging accuracy that can be achieved by the use of closed loop control of the individual mirror segments. Wind disturbances and structural couplings play a major role in limiting the position accuracy of such large structures. The main tools that we use in this study are recently developed robust control techniques for spatio-temporal systems.

**Remote and Distributed Control over Networks**
P. G. Voulgaris*
petros@decision.csl.uiuc.edu
*National Science Foundation*

Remote and distributed control over networks is a powerful concept that exploits the capabilities of the Internet (or any network) in order to remotely control critical tasks and complex dynamical interactions over long distances. The strategy of remote and distributed control also carries the great potential to lead to the development and deployment of new applications and technologies that can be very significant for the scientific and commercial worlds. Driven by the need for a systematic study of this concept, the research here aims at designing and developing novel algorithms, software, middleware, and prototypes for remote, real-time control of interacting complex systems over heterogeneous hierarchical networks built around the Internet backbone. A particular problem that is studied is the effect of decentralization and delayed information sharing in a networked system to the overall system performance.

**Robust Communication**
P. G. Voulgaris,* C. Hadjicostis, R. Touri
petros@decision.csl.uiuc.edu
*National Science Foundation*

The problem of reconstructing discrete valued signals is traditionally dealt with from a probabilistic point of view. In this project we develop a complementary, worst-case approach to this problem. The motivation comes from applications where security to malicious attacks is of paramount importance, and hence, hard performance guarantees are essential. The theoretical tools of optimal and robust control and filtering play a key role in this development. Connections to probabilistic approaches are also developed, and several trade-offs are analyzed in this new framework.

**Structured Control and Application to Atomic Force Microscopy**
P. G. Voulgaris,* M. Salapaka (Iowa State Univ.)
petros@decision.csl.uiuc.edu
*National Science Foundation*

In this project the theory of optimal and robust design is developed when structural constraints are imposed on the controller architecture. Such constraints can be generated, for example, due to limited information exchanges among different local subcontrollers in a large and complex system. Although the general problem of optimal design with decentralized control is very hard to solve, there are certain specific classes of such problems that admit a convex formulation. Included are platoons of vehicles, MEMS, networked systems, congestion control and integrated based imaging where an array of microcantilevers is used to scan the sample. The speed and the accuracy of the scan depend crucially on the coordination of the microcantilevers, which in turn requires effective structured and distributed control algorithms.

**Thermal Behavior of Materials**

**Development of MEMS Based Nanocalorimeter**
L. H. Allen*
*National Science Foundation, DMR-0108694 (Research); NSF DMR -9803019 (Equipment); ACS-PRF #37027-AC7*

Researchers are developing a new materials characterization technique that is potentially a very powerful method for directly obtaining quantitative values for small enthalpy of reactions at interfaces, surfaces, and near surface regions. This device operates at ultrafast heating (10^5 K/s) and scanning (1-scan/s) rates and is sensitive to nanometer thick films of material. This is a collaborative effort with the NNF facility at Cornell University (Ithaca, New York). To date we have achieved monolayer sensitivity, real-time in-situ characterization technique. Progress has been made not only in the fabrication of the device but also in quantitative techniques.

* Denotes principal investigator.
in analysis of heat capacity, or thermoelectrical characterization of the device.

**Mapping Thermophysical Properties with High Spatial Resolution**
D. G. Cahill,* X. Zheng
*General Electric Global Research*

We are developing and applying methods for mapping the thermophysical properties (thermal conductivity, heat capacity, and thermal expansion) of materials with 3 micron spatial resolution. These techniques are based on pump-probe measurements of optical reflectivity with picosecond time-resolution. We diffusion multiple samples prepared at GE Global Research to efficiently explore the properties of binary and ternary alloys over the entire range of compositions. Data for thermal conductivity are being used to identify the substitutional sites of a third element in an intermetallic compound and to probe the range of compositions that produce ordered phases.

**Thin Films and Charged Particles**

**Epitaxial Growth and Characterization of GaN-based Nitride Semiconductors Using Plasma-assisted Molecular Beam Epitaxy for Development of High-Speed, High-Power Heterostructure Electronic Devices**
K. Kim,* I. Adesida,* S. J. Hong, T. Day, C. W. Park
*ETRI Electronics,* Inc.

The dual objectives of this work are to grow and characterize device-quality heterostructure GaN-based films and use them to develop high-speed, high-power electronic devices. The materials growth is achieved using a plasma-assisted molecular beam epitaxy system designed and fabricated at the University of Illinois. The plasma source is capable of producing contamination-free nitrogen plasmas. The films are characterized using a variety of microanalysis techniques including RHEED, XRD, SEM, TEM, AFM, PL, CL, SIMS, and Hall measurement.

**Single Crystal Silicon Electronics on Flexible Substrates**
J. R. Abelson,* J. S. Lee, J. A. Rogers*
*Defense Advanced Research Projects Agency*
*Conducted in the Frederick Seitz Materials Research Laboratory*

The goal of this project is to fabricate thin film electronics with nearly-single-crystal performance onto flexible substrates. Using reactive magnetron sputtering, we deposit insulating a-SiNₓ and semiconducting a-Si thin films onto polymeric substrates at low temperatures. The a-Si layers are transformed into crystalline Si using excimer laser processing in the sequential lateral solidification mode (by James Im at Columbia University), and devices are processed at the Sarnoff Laboratories. We analyze the Si layer quality and evaluate the test devices.

**Nanoscale Order in Amorphous Solids: Structure, Transformations, and Electronic Properties**
J. R. Abelson,* L. N. Nittala, S. N. Bogle
*National Science Foundation, 29456*
*Conducted in the Frederick Seitz Materials Research Laboratory*

This focused research group is a broad-ranging effort to understand nanometer-scale medium range order (MRO) in amorphous semiconductors and glassy materials, including its origins, structure, and electronic effects. We are developing the fluctuation electron microscopy technique to evaluate whether solids that appear to be amorphous in diffraction in fact contain MRO. We have demonstrated that amorphous silicon cannot be described by the continuous random network model, but is paracrystalline, defined as the small grain size limit of nanocrystallinity. We are currently investigating the MRO in binary compounds, including chalcogenide glasses and transition metal borides.

**Thin-Film Electronics**

**Ge-Sb-Te Phase Change Materials: Optical and Electronic Properties, Structural Transformations, and Nanostructures**
*National Science Foundation*

We synthesize and analyze the phase-change chalcogenide GeₓSb₂Te₅ and related alloys that are used as nonvolatile data storage media: they can be reversibly transformed from an amorphous semiconducting state to a crystalline semimetallic state, which dramatically changes the optical reflectivity (as employed in RW-CVDs) and electrical conductivity (as proposed for flash memory devices). The goals are to understand the relationship between nanostructure, transformation kinetics, and the resulting electronic properties.

* Denotes principal investigator.
Surface Diffusion and Ordering Processes Exploited for Directed Self-Assembly on Amorphous Semiconductors
J. R. Abelson,* B. A. Sperling, E. Seebauer*
(Chem. & Biomol. Engr.)
National Science Foundation, 29456
Conducted in the Frederick Seitz Materials Research Laboratory
The goal of this project is to develop methods to produce regular arrays of polycrystalline silicon grains in an amorphous matrix by manipulating the surface processes of crystalline nucleation and mobile atom diffusion. We employ hot filament CVD as a deposition method, and study the evolution of surface morphology using spectroscopic ellipsometry and atomic force microscopy.

Investigation of Kinetics and Thermodynamics Properties During Reactions/Growth in Metal Systems in Devices: Silicides and W Deposition
L. H. Allen,* Z. Ma (Intel), D. Allman (LSI Logic Corp.)
Intel Corporation; LSI Logic Corporation
Conducted in the Frederick Seitz Materials Research Laboratory
Metallization plays an important role in state-of-the-art ULSI metallization process technology not only for S/D/gate contacts but also for interlayer interconnects. As device size decreases material challenges abound, including size-dependent silicide reaction and nanopipe diffusion paths for CVD W deposition. Using a new materials characterization tool, a nanocalorimetry, we are currently probing a model/metastable silicide system (Au/Si).

Cu(In,Ga)Se₂ Heterojunction Solar Cells for Extreme High-Efficiency Photovoltaic Concentrators
A. Rockett,* D. X. Liao, C. M. Mueller
National Renewable Energy Laboratory, U.S. Department of Energy, NREL AAT-1-30620-05
Conducted in the Frederick Seitz Materials Research Laboratory
The objective of this project is to demonstrate the potential for use of CuInSe₂ and related materials as the 1.00 eV energy-gap material in multijunction extremely high efficiency solar cells. Intermediate objectives include demonstration of solar cells based on p-CIS/n⁻-GaAs and p-CIS/n-Ge heterojunctions as components of multijunction high-efficiency solar cell devices.

Next-Generation Processing Methods for Cu(In,Ga)Se₂ Heterojunction Solar Cells
A. Rockett,* A. Hall, D. Hebert
Conducted in the Frederick Seitz Materials Research Laboratory
A key goal of this research is to develop a low-temperature deposition process capable of producing device-quality chalcopyrite semiconductors for solar cell applications. This is an enabling technology for multijunction solar cells. To accomplish this, a unique next-generation method for low-temperature deposition of CIGS based on the ionized physical vapor deposition (IPVD) technique will be developed. IPVD has been shown to dramatically reduce required temperatures in other thin-film coatings. IPVD is a modified sputtering approach. It supplies energy to the growing film surface though the working gas rather than by heating the substrate.

Understanding the Structural and Chemical Basis of Chalcopyrite Solar Cell Operation
A. Rockett,* I. Robertson, C. M. Li
Conducted in the Frederick Seitz Materials Research Laboratory
The goal of this proposal is to correlate the performance difference of chalcopyrite solar cells to structural and chemical inhomogeneities. Specifically, electron microscopy techniques are used to determine the chemistry and electronic structure of grain boundaries, the nature of the collecting heterojunction, and the spatial distribution of defects and impurities. The impact of these chemical and structural variations on device performance will be assessed by using computer modeling.

Atomic-Scale Mechanisms of Crystal Growth
A. Rockett*
U.S. Department of Energy, DEFG02-91ER45439
Conducted in the Frederick Seitz Materials Research Laboratory
This program seeks to improve understanding of the atomic-scale structure in thin films. The current focus is on point defects and their consequences for electronic properties of semiconductors. The program includes both theoretical and experimental approaches based on density functional theory and physical vapor deposition, respectively.

* Denotes principal investigator.
Tunneling Microscopy

Nanoelectronics: Low-Power, High-Performance Components and Circuits
U.S. Navy, ASUSG 98-152SG

Conducted in the Beckman Institute for Advanced Science and Technology

This is a Multidisciplinary Research Program of the University Research Initiative (MURI) at the Beckman Institute with the goal of combining STM nanofabrication with atomistic simulations to develop novel nanoelectronic device structures on the atomic and molecular size scale. Techniques are being developed to fabricate and test these structures in situ in the UHV STM. This program also involves collaborations with Arizona State University, University of Notre Dame, and University of California at Berkeley, to explore new interconnect schemes for nanoelectronics and to interface nanoelectronic devices with conventional microelectronic circuits.

Nanoscale Interface Characterization by UHV STM Spectroscopy
J. W. Lyding,* L. Liu, J. Yu, J. Tolomei
U.S. Office of Naval Research, N00014-00-1-0234

Conducted in the Beckman Institute for Advanced Science and Technology

This research is focused on atomic scale dopant mapping and the determination of the rms roughness and correlation lengths associated with oxide-silicon interfaces. The substitution of deuterium for hydrogen at oxide-silicon interfaces is also being studied. It has been determined with modern scaling trends that deuterium becomes increasingly effective at reducing hot carrier degradation in CMOS technology.

Journal Articles

Advanced Automation


Advanced Processing and Circuits


* Denotes principal investigator.
Kim, S., Cueva, G., and Adesida, I. *Iridium Schottky contact on In\(_{0.52}A\)l\(_{0.48}\)As*. *Electronics Letters*, 41:11, 665-667 (May 26, 2005).

Kim, S., Jang, J. H., and Adesida, I. *Enhancement-mode In\(_{0.52}A\)l\(_{0.48}\)As/In\(_{0.53}G\)a\(_{0.47}\)As/InP HEMT utilising Ir/Ti/ Pt/Au gate*. *Electronics Letters*, 41:15, 871-872 (Jul. 21, 2005).

Kumar, V., Chen, G., Guo, S., Peres, B., Eliasevich, I., and Adesida, I. *Field-plated 0.25 μm gate-length AlGaN/ GaN HEMTs on 6H-SiC with power density of 9.1 W/mm at 18 GHz*. *Electronics Letters*, 41:19, 1080-1081 (Sep. 15, 2005).


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**Bioacoustics**

Bigelow, T. A. and O'Brien, W. D. **Evaluation of the spectral fit algorithm as functions of frequency range and $\Delta k_{eff}$.** *IEEE Transactions on Ultrasonics, Ferroelectrics and Frequency Control, 52:11, 2003-2010* (Nov. 2005).


**Circuits**


Communications


Computational Science and Engineering

Computer Engineering


Control Systems


Decision and Control

Alpcan, T., Basar, T., and Tempo, R. **Randomized algorithms for stability and robustness analysis of high-speed communication networks.** *IEEE Transactions on Neural Networks, 16:5*, 1229-1241 (Sep. 2005).

Athanasopoulou, E. and Hadjicostis, C. N. **Probabilistic approaches to fault detection in networked discrete event systems.** *IEEE Transactions on Neural Networks, 16:5*, 1042-1052 (Sep. 2005).


Hadjicostis, C. N. and Verghese, G. C. **Coding approaches to fault tolerance in linear dynamic systems.** *IEEE Transactions on Information Theory, 51:1*, 210-228 (Jan. 2005).


Digital Signal and Imaging Processing


**Dynamic Systems**


Electromagnetics


Graphics and Visualization


High Frequency Devices


Lin, G. R., Kuo, H. C., Lin, C. K., and Feng, M. **Ultralow leakage In$_{0.53}$Ga$_{0.47}$As p-i-n photodetector grown on linearly graded metamorphic InGa1-xP buffered GaAs substrate.** *IEEE Journal of Quantum Electronics*, 41:6, 749-752 (Jun. 2005).

Nano-, Micro-, and Meso-Technology


Nanoscience and Technology


Networking


Nondestructive Evaluation and Testing


Operating Systems and Security


Optical Imaging


Optical Physics and Engineering


**Optoelectronics**


**Photonic Materials**


**Power and Energy Systems**

Amrhein, M. and Krein, P. T. **Dynamic simulation for analysis of hybrid electric vehicle system and subsystem interactions, including power electronics.** *IEEE Transactions on Vehicular Technology*, 54:3, 825-836 (May 2005).


**Real-Time and Embedded Systems**


**Reliable and High-Performance Computing**


Remote Sensing


**Semiconductor Lasers**


**Semiconductor Physics**


Semiconductors


Signal and Image Processing


Surfaces and Interfaces


Systems and Control


Thin Films and Charged Particles


Supercomputing Research and Development


**Thin-Film Electronics**


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**Automotive Systems**

Book Chapters

Dynamic Systems


Real-Time and Embedded Systems


Papers Presented at Conferences and Symposia

Advanced Automation


Advanced Processing and Circuits


Artificial Intelligence: Machine Learning, Vision, and Robotics


Circuits


Communications


Computer Architecture and Compilers


Computer Engineering


Construction Management


Control Systems

Alleyne, A., Ferreira, P. M., Bristow, D., Mukhopadhyay, D., Lewis, J., and Li, Q. **Process planning and a new dual-ink write head for microscale robotic deposition.** 2005 National Science Foundation Design, Service and Manufacturing Grantees and Research Conference (Scottsdale, AZ, Jan. 2005).


Decision and Control


Digital Signal and Imaging Processing


**Electromagnetics**


High Frequency Devices


Networking


Nondestructive Evaluation and Testing


Operating Systems and Security


Optical Imaging


Optical Physics and Engineering


Optoelectronics


Power and Energy Systems


**Programming Languages, Formal Systems, and Software Engineering**


Real-Time and Embedded Systems


Reliable and High-Performance Computing


Remote Sensing


Semiconductor Lasers


Semiconductor Physics


Semiconductors


Signal and Image Processing


**Systems and Control**

Dimitri, H. and Neogi, N. *Class-dependent sequencing of aircraft for landing on multiple runway systems*. 2005 Institute of Electrical and Electronics Engineers Conference on Intelligent Transportation Systems (Vienna, Austria, Sep. 2005).


**Structural Engineering and Design**


**Tunneling Microscopy**


**Theses**

**Advanced Automation**


**Advanced Processing and Circuits**


**Algorithms and Theory**


**Applied Computation Theory**


**Artificial Intelligence: Machine Learning, Vision, and Robotics**


**Automotive Systems**


Bioacoustics


Circuits


Communications


Computer Architecture and Compilers


Computer Engineering


Control Systems


Databases and Information Systems


Decision and Control


Digital Signal and Imaging Processing


Electromagnetics


High Frequency Devices


Nanoscience and Technology


Networking


Operating Systems and Security


Optical Physics and Engineering


Parallel Processing


Power and Energy Systems


Programming Languages, Formal Systems, and Software Engineering

<table>
<thead>
<tr>
<th>Author</th>
<th>Title</th>
<th>Type</th>
<th>Advisor(s)</th>
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<tbody>
<tr>
<td>Wu, M.</td>
<td>Component-based software testing for real time system.</td>
<td>M.S. thesis</td>
<td>L. R. Sha</td>
<td>2005</td>
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<td>Dabrowski, M. J.</td>
<td>The design of a software system for a small space satellite.</td>
<td>M.S. thesis</td>
<td>M. I. Frank</td>
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<td>Daly, D.</td>
<td>Bounded aggregation techniques to solve large Markov models.</td>
<td>Ph.D. thesis</td>
<td>W. H. Sanders</td>
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<td>Miller, B.</td>
<td>The masked-history predictor: A two-level branch predictor with selective global history.</td>
<td>M.S. thesis</td>
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<td>Sachdeva, K.</td>
<td>Load values and the branches that use them.</td>
<td>M.S. thesis</td>
<td>S. J. Patel</td>
<td>2005</td>
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<td>Steiner, I.</td>
<td>Future compilation requirements for emerging driving general-purpose applications.</td>
<td>M.S. thesis</td>
<td>W. W. Hwu</td>
<td>2005</td>
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<td>Tucknott, M.</td>
<td>Reuse of previously fetched instructions through the use of a reorder buffer cache.</td>
<td>M.S. thesis</td>
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<td>Name</td>
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<td>Cheng, J.</td>
<td>Third-order distortion and gain analysis for MOS mixers.</td>
<td>M.S.</td>
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<td>Hagen, C.</td>
<td>Software-defined radio design in LabVIEW.</td>
<td>M.S.</td>
<td>S. J. Franke</td>
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<td>Hwang, A. D.</td>
<td>Temperature estimation using meteor echo decay times in the mesosphere and lower thermosphere.</td>
<td>M.S.</td>
<td>S. J. Franke</td>
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<td>Mukhopadhyay, C.</td>
<td>Booster amplification at 1064 nm in a fiber-laser lidar transmitter for frequency triple operation near 355 nm.</td>
<td>M.S.</td>
<td>G. R. Swenson</td>
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<td>Niu, X.</td>
<td>Narrow linewidth-distributed Bragg reflector lasers operating at 850 nm.</td>
<td>M.S.</td>
<td>J. J. Coleman</td>
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<td>Lu, M.</td>
<td>3D self-consistent simulation of single-qubit operation by modulation of the hyperfine interaction in phosphorus-doped MOS structure</td>
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<td>Nawaz, M.</td>
<td>Optic phonon-limited hole mobility in silicon nanowires: Continuous versus quantized modes.</td>
<td>M.S.</td>
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<td>Wang, X.</td>
<td>Modeling the effect of channel water on ion transport using Monte Carlo scattering.</td>
<td>M.S.</td>
<td>K. Hess</td>
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<td>Aksamija, Z.</td>
<td>Monte Carlo simulation of heat generation in silicon, including the full phonon dispersion.</td>
<td>M.S.</td>
<td>U. Ravaioli</td>
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<td>Kline, J. S.</td>
<td>Silicon nanoelectronic devices fabricated by ultra-high vacuum, scanning tunneling microscope nanolithography.</td>
<td>Ph.D.</td>
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<td>Mohamed, M.</td>
<td>Monte Carlo simulation of nonlocal effects in electronic devices.</td>
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<td>Ravishankar, R.</td>
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<td>Narla, D.</td>
<td>Extraction of direct sound and reflectivity from room impulse responses.</td>
<td>M.S.</td>
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<td>Petrovic, N.</td>
<td>Graphical models for video understanding.</td>
<td>Ph.D.</td>
<td>T. S. Huang</td>
<td>2005</td>
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</table>


Surfaces and Interfaces


Systems and Control


Awards and Honors

**John R. Abelson**
IBM University Partnership Award, 1995-1997
Fakultetsopponent (External Examiner), University of Linkoping, Sweden, 1995
Xerox Award for Faculty Research, University of Illinois College of Engineering, 1996
Engineering Council Award for Excellence in Advising, University of Illinois, 1997
Incomplete List of Teachers Ranked as Excellent, University of Illinois, 2000, 2002
Fellow, American Vacuum Society, 2004

**Ilesanmi Adesida**
Scientific Member, Bohmische Physical Society
Fellow, Institute of Electrical and Electronics Engineers (IEEE)

**Engineering Council Advisors List for Outstanding Advising, University of Illinois, 1993, 1999**
Distinguished Lecturer, IEEE Electronic Device Society, 1977-1999
University Scholar, University of Illinois, 1997, 1999
Associate Member, Center for Advanced Study, 2000-2001

**Vikram Adve**
Best Paper Award, 15th Workshop on Parallel and Distributed Simulation, May 2001
C. W. Gear Outstanding Junior Faculty Award, University of Illinois Department of Computer Science, 2002
Associate Editor, *ACM Transactions on Programming Languages and Systems*, 2003-
Best Paper Award, Programming Language Design and Implementation, 2005

**Gul A. Agha**
Young Investigator Award, U.S. Office of Naval Research, 1989
Incentive for Excellence Award, Digital Equipment Corporation Faculty Program, 1990
Fellow, University of Illinois Center for Advanced Study, 1992-1993
International Lecturer, Association for Computing Machinery (ACM), 1991-2000
Golden Core Member, Institute of Electrical and Electronics Engineers (IEEE) Computer Society, 1999
Meritorious Service Award, IEEE Computer Society, 1999
Editor-in-Chief, *ACM Computing Surveys*, 2000-
Fellow, IEEE Computer Society, 2002
Member, European Academy of Sciences, 2003
Arthur Schofstall Distinguished Lecturer, Renssleear Polytechnic Institute, 2003

**Narendra Ahuja**
Fellow, American Association for the Advancement of Science
Fellow, American Association for Artificial Intelligence Fellow, Association for Computing Machinery
Fellow, Institute of Electrical and Electronics Engineers Fellow, International Association for Pattern Recognition Fellow, International Society for Optical Engineering
University Scholar, University of Illinois
Beckman Associate, University of Illinois Center for Advanced Study, 1990-1991
Associate, University of Illinois Center for Advanced Study, 1998
Donald Biggar Willet Professorship, University of Illinois College of Engineering, 1999
Incomplete List of Teachers Ranked as Excellent by Their Students, 2002

Jont Allen
IBM Faculty Award, 2004

Leslie H. Allen
Racheff Professor of Materials Science, University of Illinois College of Engineering, 1991-1993
Advisors List for Advising Excellence, University of Illinois, 1999, 2002
Outstanding Scholar Faculty Recognition, Alpha Delta Pi, University of Illinois, 1999

Andrew G. Alleyne
Outstanding Graduate Student Instructor Award, 1990-1991
"Incomplete List of Teachers Ranked as Excellent by Their Students," University of Illinois, Spring 1995, Fall 2004
Faculty Early Career Development (CAREER) Program Award, National Science Foundation, 1996
Engineering Council Award for Excellence in Advising, University of Illinois College of Engineering, 1998, 1999
Honorable Mention for paper (one of five finalist papers) at the XIVth International Federation of Automatic Control Congress, Beijing, Peoples' Republic of China, 1999
Xerox Award for Faculty Research, University of Illinois College of Engineering, 2000
Best Paper Award, American Society of Mechanical Engineers International Mechanical Engineering Congress and Exposition, Dynamic Systems and Control Division, 2000
Who's Who Among America's Teachers, 2000
Accenture Award for Excellence in Advising, University of Illinois College of Engineering, 2001, 2003
Fulbright Fellowship, 2002-2003
College of Engineering Ralph M. and Catherine V. Fisher Professor, University of Illinois College of Engineering, 2002-2005

Student Best Paper Award, American Society of Mechanical Engineering International Mechanical Engineers Congress and Exposition, Dynamic Systems and Control Division, 2002
Best Paper Finalist (top 12 out of 150), 6th International Symposium on Advanced Vehicle Control, 2002
Ralph R. Teetor Educational Award, Society of Automotive Engineers, 2003
Distinguished Lecturer, Institute of Electrical and Electronics Engineers Control Systems Society, 2004-2007
Outstanding Young Investigator Award, American Society of Mechanical Engineers Dynamic Systems and Control Division, 2003
Invited Participant, National Academy of Engineering 19th Annual Symposium on Frontiers of Engineering, 2004
Fellow, American Society of Mechanical Engineers, 2005
Honorable Mention, Campus Award for Innovation in Undergraduate Instruction, University of Illinois, 2005
Honorable Mention, Campus Award for Excellence in Graduate and Professional Teaching, University of Illinois, 2006

Tamer Basar
Member, National Academy of Engineering
Fellow, Institute of Electrical and Electronics Engineers (IEEE)
Fellow, International Federation of Automatic Control (IFAC)
Member, European Academy of Sciences
Editor, IEEE Transactions on Automatic Control, 1992-1994
Associate Member, University of Illinois Center for Advanced Study, 1993-1994
Nearing Distinguished Professor of Electrical and Computer Engineering, University of Illinois, 1998-1999
Zaborszky Lecturer, Washington University, St. Louis, 1999
IEEE Millennium Medal, 2000
President, IEEE Control Systems Society, 2000
NASA "Revolutionize Aviation Goal" Award, 2001
Honorary Editor, J. Applied and Computational Mathematics, 2002-
Penner Distinguished Lecturer, University of California, San Diego, 2003
Editor-in-Chief, Automatica, 2004-
Tau Beta Pi Daniel C. Drucker Eminent Faculty Award, University of Illinois College of Engineering, 2004
Hendrik W. Bode Lecture Prize, IEEE Control Systems Society, 2004
Giorgio Quazza Medal, IFAC, 2005
Outstanding Service Award, IFAC, 2005
Professor, Center for Advanced Study, University of Illinois, 2005-

Stephen G. Bishop
Fellow, American Association for the Advancement of Science
Fellow, American Physical Society
Fellow, Optical Society of America
Board of Trustees, Gettysburg College, 1992-

Richard Blahut
Member, National Academy of Engineering, 1990
Fellow, IBM, 1980
Fellow, Institute of Electrical and Electronics Engineers, 1981
Fellowship, Japan Society for the Promotion of Science, 1982
Henry Magnuski Professor, 2000
Daniel C. Drucker Eminent Faculty Award, University of Illinois College of Engineering, 2000
Institute of Electrical and Electronics Engineers (IEEE) Claude E. Shannon Award, 2005

Yoram Bresler
Fellow, Institute of Electrical and Electronics Engineers (IEEE)
Technion Fellowship, 1995-1996
University Scholar, University of Illinois, 1999
Associate, University of Illinois Center for Advanced Study, 2001-2002

Donna J. Brown
Outstanding Young Woman of America, 1984

David Cahill
Fellow, American Vacuum Society
Peter Mark Memorial Award, American Vacuum Society, 1998
University Scholar, University of Illinois, 2000-2003
Willett Faculty Scholar Award, University of Illinois, 2002-2004
Donald B. Willett Professor of Engineering, University of Illinois, 2005

Roy H. Campbell
Senior Visiting Research Fellowship at University of Newcastle upon Tyne, Science and Engineering Research Council of Great Britain, 1981-1983

Information Technology Committee, Illinois Terrorism Task Force, 2002-2003
Sohaib and Sara Abbasi Professor in Computer Science, University of Illinois, 2004-

Andreas Cangellaris
Fellow, Institute of Electrical and Electronics Engineers (IEEE)
Outstanding Technical Paper Award, 3rd Electronics Packaging Technology Conference (EPTC), Singapore, 2000

Nicholas Carter
Distinguished Paper Award, International Symposium, Tokyo, Japan, 2000

Keh-Yung Cheng
Fellow, Institute of Electrical and Electronics Engineers (IEEE), 2001
Fellow, American Association for the Advancement of Science (AAAS), 2004
Ministry of Education Distinguished Visiting Chair Professor, National Tsing-Hua University, Hsinchu, Taiwan, 2003-2004

James J. Coleman
Fellow, American Association for the Advancement of Science
Fellow, American Physical Society
Fellow, Institute of Electrical and Electronics Engineers (IEEE)
Fellow, Optical Society of America
IEEE LEOS William Streifer Scientific Achievement Award
Franklin Woeltge Professorship, University of Illinois Electrical and Computer Engineering Department, 2002

Gerald DeJong
Faculty Assistant Grant, Exxon Mobil Corporation, 1982
Arnold O. Beckman Research Award, University of Illinois Research Board, 1984
Faculty Recognition Grant, Alcoa Foundation, 1989
Fellow, American Association for Artificial Intelligence, 1992
International Scientist of the Year, International Biographical Centre, 2001

Minh Do
Faculty Early Career Development (CAREER) Award, National Science Foundation, 2003
Best Paper Award at the Institute of Electrical and Electronics Engineers (IEEE) International Conference on Acoustics, Speech, and Signal Processing, 2005

Geir E. Dullerud
National Sciences and Engineering Research Council of Canada Initiation Grant, 1996
Faculty Early Career Development (CAREER) Program Award, National Science Foundation, 1999
Willett Faculty Scholar Award, University of Illinois College of Engineering, 2002-2005
Listed in the Daily Illini "Incomplete List of Teachers Ranked as Excellent by Their Students," Fall 2004

James G. Eden
Aron Kressel Award, Institute of Electrical and Electronics Engineers Lasers and Electro-Optics Society, 2005
Fellow, American Physical Society
Fellow, Institute of Electrical and Electronics Engineers (IEEE)
Fellow, Optical Society of America
Associate, University of Illinois Center for Advanced Study, 1987-1988
Board of Governors, IEEE Lasers and Electro-Optics Society, 1990-1993
Associate Editor, Photonics Technology Letters, 1990-1994
Vice President (Technical Affairs), IEEE Lasers and Electro-Optics Society, 1993-1995
Editor, IEEE Journal of Selected Topics in Quantum Electronics, 1996
James F. Towey University Scholar, University of Illinois, 1996-1999
President, IEEE Lasers and Electro-Optics Society (LEOS), 1998
Faculty Outstanding Teaching Award, University of Illinois Department of Electrical and Computer Engineering, 2000
IEEE Third Millennium Medal, 2000
Faculty Advisors List, University of Illinois College of Engineering, 2001, 2004
Awards Chair, IEEE LEOS, 2003, 2004
Distinguished Lecturer, IEEE LEOS, 2003-2005

Gert Ehrlich, Emeritus
Member, National Academy of Sciences
Fellow, New York Academy of Sciences
Fellow, American Physical Society
Fellow, American Vacuum Society
Medard W. Welch Award, American Vacuum Society, 1979
Kendall Award in Colloid or Surface Chemistry, American Ceramic Society, 1982
Fellow, J. S. Guggenheim Foundation, 1984
Senior U.S. Scientist Award, Alexander von Humboldt Foundation, Germany, 1992
Tau Beta Pi Daniel C. Drucker Eminent Faculty Award, University of Illinois College of Engineering, 2002

Steven J. Franke
Senior Member, Institute of Electrical and Electronics Engineers

Chester S. Gardner
Fellow, American Association for the Advancement of Science
Fellow, Institute of Electrical and Electronics Engineers (IEEE)
Fellow, Optical Society of America
CEDAR Prize Lecture, National Science Foundation, 1996

Christoforos Hadjicostis
Fellow, Josephine de Karman
Fellow, National Semiconductor Corporation
Fellow, Grass Instrument Company
Faculty Early Career Development Program (CAREER) Award, National Science Foundation, 2001
Recognized Reviewer of Institute of Electrical and Electronics Engineers (IEEE) IEEE Transaction on Automatic Control, 2001
Faculty Outstanding Teaching Award, University of Illinois Electrical and Computer Engineering Department, 2003
Engineering Council Award for Excellence in Advising, University of Illinois College of Engineering, 2004
Willett Faculty Scholar, University of Illinois College of Engineering, 2005
Senior Member, IEEE, 2005

Bruce E. Hajek
Member, National Academy of Engineering
Fellow, Institute of Electrical and Electronics Engineers (IEEE)
Beckman Associate, University of Illinois Center for Advanced Study, 1984
University Scholar, University of Illinois, 1986
Fellow, J. S. Guggenheim Foundation, 1992
President, IEEE Information Theory Society, 1995
<table>
<thead>
<tr>
<th>Name</th>
<th>Awards and Recognition</th>
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<tbody>
<tr>
<td><strong>IEEE Koji Kobayashi</strong></td>
<td>Computers and Communications Award, 2003</td>
</tr>
<tr>
<td><strong>Ibrahim Hajj, Emeritus</strong></td>
<td>Fellow, Institute of Electrical and Electronics Engineers (IEEE)</td>
</tr>
<tr>
<td></td>
<td>Best Paper Award, Southwest Symposium on Mixed-Signal Design, 1999</td>
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<tr>
<td></td>
<td>Golden Jubilee Award, IEEE Circuits and Systems Society, 1999</td>
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<tr>
<td></td>
<td>Meritorious Service Award, University of Illinois, 2001</td>
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<tr>
<td><strong>Mark Hasegawa-Johnson</strong></td>
<td>Senior Member, Institute of Electrical and Electronics Engineers (IEEE)</td>
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<tr>
<td></td>
<td>Faculty Early Career Development Program (CAREER) Award, National Science Foundation, 2002</td>
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<tr>
<td><strong>Karl Hess</strong></td>
<td>Member, National Academy of Engineering, 2001</td>
</tr>
<tr>
<td></td>
<td>Member, National Academy of Sciences, 2003</td>
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<tr>
<td></td>
<td>Fellow, American Academy of Arts and Sciences</td>
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<td>Fellow, American Association for the Advancement of Science</td>
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<td>Fellow, Institute of Electrical and Electronics Engineers (IEEE)</td>
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<td>Fellow, American Physical Society</td>
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<tr>
<td></td>
<td>Louis A. Fridrich University Scholar, 1993</td>
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<tr>
<td></td>
<td>Swanlund Chair in Electrical and Computer Engineering, University of Illinois, 1996-</td>
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<tr>
<td></td>
<td>Professor, University of Illinois Center for Advanced Study, 1998-</td>
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<td></td>
<td>Heinrich Welker Memorial Award, 2001</td>
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<tr>
<td></td>
<td>Honorary Doctor of Sciences, ETH Zuerich, 2003</td>
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<tr>
<td><strong>Thomas S. Huang</strong></td>
<td>Member, National Academy of Engineering</td>
</tr>
<tr>
<td></td>
<td>Foreign Member, Chinese Academy of Engineering</td>
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<td>Foreign Member, Chinese Academy of Sciences</td>
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<tr>
<td></td>
<td>Fellow, Institute of Electrical and Electronics Engineers (IEEE)</td>
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<td>Fellow, International Association of Pattern Recognition</td>
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<td>Fellow, Japan Society for the Promotion of Science</td>
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<td>Fellow, Optical Society of America (SPIE)</td>
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<td>Fellow, The International Optical Society</td>
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<tr>
<td></td>
<td>Fellow, J. S. Guggenheim Foundation, 1971</td>
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<tr>
<td></td>
<td>Associate, University of Illinois Center for Advanced Study, 1990</td>
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<tr>
<td><strong>University Scholar, University of Illinois, 1990</strong></td>
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<tr>
<td><strong>Fujitsu Endowed Chair Visiting Professor, University of Tokyo, 1993</strong></td>
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<tr>
<td><strong>IEEE Signal Processing Society Distinguished Lecturer, 1993-1994</strong></td>
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<tr>
<td><strong>William L. Everitt Distinguished Professor, University of Illinois, 1996-</strong></td>
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<tr>
<td><strong>Peter H. Bartels Visiting Professor, University of Washington, 1997</strong></td>
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<tr>
<td><strong>Center for Advanced Study Professor, University of Illinois at Urbana-Champaign, 2003-</strong></td>
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<tr>
<td><strong>Honored as a Pioneer in Signal Processing at the IEEE ICASSP, 1998</strong></td>
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<tr>
<td><strong>Honda Lifetime Achievement Award, 2000</strong></td>
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<td><strong>IEEE Third Millennium Medal, 2000</strong></td>
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<td><strong>IEEE Jack Kilby Medal, 2001</strong></td>
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<tr>
<td><strong>King-Sun Fu Prize, International Association Pattern Recognition, 2002</strong></td>
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<tr>
<td><strong>Pan Wen-Yuan Foundation Outstanding Research Award, 2002</strong></td>
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<tr>
<td><strong>IBM Faculty Award, 2002, 2003</strong></td>
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<tr>
<td><strong>Tau Beta Pi Daniel Drucker Eminent Engineering Faculty Award, University of Illinois College of Engineering, 2005</strong></td>
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<tr>
<td><strong>Okawa Award for Information and Telecommunication Technology, 2005</strong></td>
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<tr>
<td><strong>Scientist of the Year Award, IS&amp;T and SPIE Electronic Imaging, 2006</strong></td>
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<tr>
<td><strong>Wen-Mei Hwu</strong></td>
<td>Fellow, Institute of Electrical and Electronics Engineers (IEEE)</td>
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<td></td>
<td>IEEE Computer Society Certificate of Appreciation, for Service as Both General and Program Chair for the Silver Anniversary MICRO Conference</td>
</tr>
<tr>
<td></td>
<td>Fellow, Association of Computing Machinery</td>
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<tr>
<td></td>
<td>Intel Associate Professor, University of Illinois Electrical and Computer Engineering Department, 1992-1993</td>
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<tr>
<td><strong>University Scholar, University of Illinois, 1994</strong></td>
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<tr>
<td><strong>Franklin W. Woeltge Professorship, University of Illinois Electrical and Computer Engineering Department, 2000</strong></td>
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<tr>
<td><strong>Tau Beta Pi Daniel Drucker Eminent Engineering Faculty Award, University of Illinois College of Engineering, 2001</strong></td>
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<tr>
<td><strong>Computerworld Medal Honors, 2002</strong></td>
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<tr>
<td><strong>Faculty Outstanding Teaching Award, University of Illinois Electrical and Computer Engineering Department, 2002</strong></td>
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<tr>
<td><strong>Sanders III Advanced Micro Devices, Inc. Endowed Chair, University of Illinois Electrical and Computer Engineering Department, 2003</strong></td>
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</tr>
</tbody>
</table>
Ravishankar K. Iyer
Fellow, Association for Computing Machinery
Fellow, Institute of Electrical and Electronics Engineers (IEEE)
Fellow, American Association for the Advancement of Science
Associate Fellow, American Institute of Aeronautics and Astronautics
Distinguished Visitor, IEEE, 1989-
Distinguished Service Certificate, American Institute of Aeronautics and Astronautics, 1997
George and Ann Fisher Distinguished Professor, University of Illinois College of Engineering, 1998-
Emanuel R. Piore Award, IEEE, 2001

Douglas L. Jones
Fulbright Fellowship, 1987
Fellow, Institute of Electrical and Electronics Engineers

Farzad Kamalabadi
Faculty Early Career Development Program (CAREER) Award, National Science Foundation, 2002

Ralf Koetter
Co-Editor-in-Chief, Special Issue of the IEEE Transactions on Information Theory
Associate Editor, IEEE Transactions on Communications, 1999-2000
Associate Editor, IEEE Transactions on Information Theory, 2000-
Faculty Early Career Development Program (CAREER) Award, National Science Foundation, 2000
Incomplete List of Teachers Rated Excellent, 2000
Collins Scholar, 2000
IBM Partnership Award, 2001
Willet Faculty Scholar, University of Illinois, 2002

Philip T. Krein
Fellow, Institute of Electrical and Electronics Engineers (IEEE)
William E. Newell Power Electronics Award, IEEE
Grainger endowed Director's Chair in Electric Machinery and Electromechanics
Grainger Associate, University of Illinois Department of Electrical and Computer Engineering, 1995-2002
Fulbright Scholar, 1997-1998
Past President, IEEE Power Electronics Society
University Scholar, University of Illinois, 1999-2002
Division II Director, IEEE, 2003-2004
Distinguished Lecturer, IEEE Power Electronics Society

P. R. Kumar
Fellow, Institute of Electrical and Electronics Engineers (IEEE)
Franklin W. Woeltge Professor of Electrical and Computer Engineering, University of Illinois, 2000-
Field Award, Control Systems, IEEE

Jean-Pierre Leburton
Member, New York Academy of Science
Fellow, American Association for Advancement of Science
Fellow, American Physical Society
Fellow, Electro Chemical Society
Fellow, Institute of Electrical and Electronics Engineers
Fellow, Optical Society of America
Associate, University of Illinois Center for Advanced Study
Hitachi Ltd. Quantum Materials Chair, Research Center for Advanced Sciences and Technology, University of Tokyo, 1992
Chevalier Dans L'Ordre Des Palmes Academiques, 1994
King Albert II of Belgium, Round Table on the "Mobility of European Research Scientist" European Science and Technology Commission, 2001
Inaugural Montefiore Distinguished Lecture, Penn State University, 2002
Gregory Stillman Professor in Electrical and Computer Engineering, University of Illinois College of Engineering, 2004
Gold Medal for Scientific Achievement, 75th Anniversary of the Alumnus Association of the University of Liege, Belgium, 2004
Quantum Devices Award, Outstanding Achievement in the Area of Compound Semiconductor Research, 2004

Stephen Levinson
Fellow, Acoustical Society of America
Fellow, Institute of Electrical and Electronics Engineers

Zhi-Pei Liang
University Scholar Award
Beckman Fellow, University of Illinois Center for Advanced Study, 1997
Henry Magnuski Scholar, University of Illinois College of Engineering, 1999

Daniel Liberzon
Faculty Early Career Development Program (CAREER) Award, National Science Foundation, 2002
Young Author Prize, International Federation of Automatic Control, 2002
Liang Y. Liu
Advisory Award, University of Illinois College of Engineering, 2002, 2003, 2004
Fellowship, W. E. O’Neil Construction Faculty Research, 2002-2004
Teaching Award, University of Illinois College of Engineering, 2003

Michael C. Loui
Fellow, Institute of Electrical and Electronics Engineers (IEEE)
University Distinguished Teacher/Scholar Carnegie Scholar, Carnegie Foundation for the Advancement of Teaching

Steven Lumetta
Faculty Early Career Development Program (CAREER) Award, National Science Foundation, 2000

Joseph W. Lyding
IBM Postdoctoral Fellow, 1983
Beckman Fellow, University of Illinois Center for Advanced Study, 1987-1988
Associate, University of Illinois Center for Advanced Study, 1996-1997
Fellow, American Physical Society, 1997
University Scholar, University of Illinois, 1997
Fellow, American Vacuum Society, 2000

Juraj V. Medanic
Dusan Mitroovic Award for Best Paper in Control, ETAN (Yugoslavia), 1983

Sean Meyn
Fulbright Research Scholar for Research on Optimization and Network Scheduling, 1997

Pierre Moulin
Associate Editor, Institute of Electrical and Electronics Engineers (IEEE) *IEEE Transactions on Information Theory*, 1996-1998
Incomplete List of Teachers Ranked as Excellent by their Students, 1996, 1999, 2000, 2005
Associate Editor, *IEEE Transactions on Image Processing*, 1999-
Area Editor, *IEEE Transactions on Image Processing*, 2002-
University of Illinois Center for Advanced Study, 2003

IEEE Fellow, 2003
Founding Editor-in-Chief, *IEEE Transactions on Information Forensics and Security*, 2005-
Board of Governors, IEEE Signal Processing Society, 2005-
Sony Faculty Award, 2005

Klara Nahrstedt
Weierstrass Prize, Weierstrass Institute of Mathematics, Berlin, 1985
Faculty Early Career Development Program (CAREER) Award, National Science Foundation (NSF), 1996
NASA Space Act Award, NSF, 1996
Xerox Award for Junior Faculty Research, University of Illinois College of Engineering, 1998
C. W. Gear Faculty Award, University of Illinois Department of Computer Science, 1999
Best Tutorial Paper Award, Institute of Electrical and Electronics Engineers (IEEE), for "An Overview of Quality of Service Routing for Next-Generation High-Speed Networks: Problems and Solutions," 1999
Campus Award for Innovation in Undergraduate Instruction Using Educational Technologies, University of Illinois, 2000
Associate Editor, *ACM Computer Communications Reviews*, 2000-
Editor-in-Chief, *ACM Multimedia Systems Journal*, 2001-
Ralph M. and Catherine V. Fisher Professorship, University of Illinois College of Engineering, 2002-

David Nicol
Marion and Jason Whiting Fellowship, Oxford University, 2000
Fellow, Institute of Electrical and Electronics Engineers Best Paper Award, IPSI Studenica Conference, 2004

William D. O’Brien, Jr.
Founding Fellow, American Institute of Medical and Biological Engineering
Fellow, Acoustical Society of America
Fellow and Past President, American Institute of Ultrasound in Medicine
Fellow, Institute of Electrical and Electronics Engineers (IEEE)
Past President, American Institute of Ultrasound in Medicine
Past President, IEEE Sonics and Ultrasonics Group
Past Treasurer, World Federation of Ultrasound in Medicine and Biology
Honorary Member, Society of Vascular Technology
Centennial Medal, IEEE, 1984
Distinguished Lecturer, IEEE Ultrasonics, Ferroelectrics and Frequency Control Society, 1997-1998
IEEE Third Millennium Medal, 2000
Donald Biggar Willet Professor of Engineering, College of Engineering, University of Illinois, 2003-
Distinguished Service Award, IEEE Ultrasonics, Ferroelectrics, and Frequency Control Society, 2003

**Janak H. Patel**
Fellow, Institute of Electrical and Electronics Engineers (IEEE)
Fellow, Association of Computing Machinery
Donald Biggar Willet Professor, University of Illinois College of Engineering, 1999

**William R. Perkins**
Life Fellow, Institute of Electrical and Electronics Engineers (IEEE)
Past President, IEEE Control Systems Society
Distinguished Member, IEEE Control Systems Society
Centennial Medal, IEEE, 1984
Distinguished Lecturer, IEEE Control Systems Society, 1986-1987
President, American Automatic Control Council, 1996-1997
IEEE Third Millennium Medal, 2000
NASA "Turning Goals into Reality" Award, 2001

**Constantine D. Polychronopoulos**
Board of Directors, Association for Computing Machinery SIGARCH
Editor, *International Journal of High-Speed Computing*, 1989-
Mitsubishi Endowed Professorship, University of Tokyo, 1993
Best Research Paper Award, Institute of Electrical and Electronics Engineers Supercomputing, 2000

**Umberto Ravaioli**
Fellow, Institute of Physics

Fellow, Institute of Electrical and Electronics Engineers, 2003

**Angus A. Rockett**
Xerox Award for Faculty Research, University of Illinois College of Engineering, 1992
Everett Teaching Award, University of Illinois College of Engineering, 1993
Fellow, American Vacuum Society, 1998
Donald Burnett Teacher of the Year Award, University of Illinois Materials Science and Engineering Department, 1998
Stanley H. Pierce Award, University of Illinois College of Engineering, 2002

**Elyse Rosenbaum**
Best Student Paper Award (co-author, faculty advisor), EOS/ESD Symposium, 2003
Bliss Faculty Scholar Award, University of Illinois, 2005

**William Sanders**
Fellow, Institute of Electrical and Electronics Engineers
Fellow, Association for Computing Machinery
Elected Member, IFIP Working Group 10.4 on Dependable Computing
Member, Sigma Xi
Member, Eta Kappa Nu
Member, Motorola Research Visionary Board (RVB), 2005
Member, Advisory Board for the Computational Sciences and Engineering Division (CSED) for Oak Ridge National Laboratory, 2005
Elected Member, Board of Directors, ACM Sigmetrics, 2001-2003, 2005-2007
Engineering Council Award for Excellence in Advising, 2002, 2002
Best Paper, Pacific Rim International Symposium on Dependable Computing, Tsukuba, Japan, 2002
Incomplete List of Teachers Ranked as Excellent by their Students, University of Illinois, 2002, 2003
Donald Biggar Willett Professor of Engineering, University of Illinois College of Engineering, 2005

**Dilip V. Sarwate**
Fellow, Institute of Electrical and Electronics Engineers (IEEE)
Peter W. Sauer  
Member, National Academy of Engineering  
Fellow, Institute of Electrical and Electronics Engineers (IEEE)  
U.S. Air Force Meritorious Service Medal, 1993  
Honorary Professional Degree in Electrical Engineering, University of Missouri-Rolla, 1995  
Academy of Electrical Engineering, University of Missouri-Rolla, 1996  
Outstanding Electrical Engineer Award, Purdue University, 2004  
Grainger Chair Professor of Electrical Engineering, University of Illinois, 1998-  
IEEE Third Millennium Medal, 2000

Lui Sha  
Fellow, Institute of Electrical and Electronics Engineers  
Associate Editor, International Journal of Real-Time Systems, 1992-  
Area Editor, IEEE Computer, 1993-1995  
GE Scholar, University of Illinois Academy for Excellence in Engineering Education, 1999  
Co-Chair, IEEE Real-Time and Embedded Technology and Applications Symposium, 2001  
Associate Editor, IEEE Transactions on Parallel and Distributed Systems, 2001-2002

Naresh Shanbhag  
Distinguished Lecturer, Institute of Electrical and Electronics Engineers Circuits and Systems Society, 1997-1999  
Best Paper Award, IEEE Transactions on VLSI Systems, 2001

Andrew Singer  
Hughes Aircraft Graduate Fellow  
Faculty Early Career Development Program (CAREER) Award, National Science Foundation, 2001  
ONR Special Research Award in Ocean Acoustics 2001  
Outstanding Undergraduate Advisor Award, University of Illinois College of Engineering, 2002  
Willett Faculty Scholar Award, University of Illinois, 2002

Mark W. Spong  
Fellow, Institute of Electrical and Electronics Engineers (IEEE)  
Phi Beta Kappa  
Visiting Professor, Catholic University, Leuven, Belgium, 1997

Editor, IEEE Transactions on Control Systems Technology, 1997-2000  
Visiting Professor, National University of Singapore, 1999  
Engineering Council Advisors List for Outstanding Advising, University of Illinois, 1999, 2005  
Senior U. S. Scientist Research Prize, Alexander von Humboldt Foundation, Germany, 1999  
Visiting Professor, Technical University of Munich, 2000  
Vice President for Publications, IEEE Control Systems Society, 2000-2002  
IEEE Third Millennium Medal, 2000  
Southwest Mechanics Lecture Series Distinguished Speaker, 2001  
Distinguished Member Award, IEEE Control Systems Society, 2002  
O. Hugo Schuck Award, American Automatic Control Council, 2002  
Donald Biggar Willet Professor of Engineering, 2003  
John R. Ragazzini Control Education Award, American Automatic Control Council, 2004  
President, IEEE Control Systems Society, 2005

R. S. Sreenivas  
Research Initiation Award, National Science Foundation, 1994

Timothy N. Trick, Emeritus  
Fellow, American Association for the Advancement of Science  
Fellow, Institute of Electrical and Electronics Engineers (IEEE)  
Fellow, International Engineering Consortium  
Past President, IEEE Circuits and Systems Society  
Past Vice President, IEEE Publication Board  
Centennial Medal, IEEE, 1984  
IEEE Board of Directors, 1986-1989  
National Engineering Consortium Board of Directors, 1990-  
President, National Electrical Engineering Department Heads Association, 1994-1995  
Golden Jubilee Medal for Extraordinary Contributions to the IEEE Circuit and Systems Society, 2000  
IEEE Third Millennium Medal, 2000  
Alumni Award for Excellence, University of Dayton, School of Engineering, 2000  
Outstanding Electrical Engineer Award, Purdue University, 2001  
University Research Award, Semiconductor Industry Association, 2002  
Board of Governors, Eta Kappa Nu, 2002-2005
John Tucker
Senior Member, Institute of Electrical and Electronics Engineers (IEEE)
Fellow, American Physical Society
Microwave Pioneer Award, IEEE, 2002

Nitin Vaidya
Distinguished Visitor Program Speaker, Institute of Electrical and Electronics Engineers (IEEE) Computer Society, 1998-2001
Best Paper Award, The Eighth International Conference on Personal Wireless Communications (PWC), Venice, 2003
Editor-in-Chief, ACM SIGMOBILE Mobile Computing and Communications Review (MC2R), 2003-2004
Editor-in-Chief, IEEE Transactions on Mobile Computing, 2005-

Venu Veeravalli
Senior Member, Institute of Electrical and Electronics Engineers (IEEE), 1998
Chair, IEEE Ithaca Section, 1999-2000
Editor, Communications in Information and Systems (CIS), 2000
Associate Editor, IEEE Journal on Selected Areas in Communications–Wireless Series, 2000-2001
Co-organizer of the National Academy of Engineering, Frontiers of Engineering Conference, 2001
Associate Editor, Detection & Estimation, IEEE Transactions on Information Theory, 2001-2003
Beckman Associate for the Center for Advanced Study, University of Illinois, 2002-2003
Invited Participant in the National Academy of Engineering, Frontiers of Engineering Conference, 2002

Pramod Viswanath
Eliahu Jury Award from Department of EECS, University of California–Berkeley, 2000
Bernard Friedman Award from Mathematics Department, University of California–Berkeley, 2000
Faculty Early Career Development Program (CAREER) Award, National Science Foundation, 2003

Petros G. Voulgaris
Research Initiation Award, National Science Foundation, 1993
Young Investigator Award, U.S. Office of Naval Research, 1995
Xerox Award for Faculty Research, University of Illinois College of Engineering, 1996

Benjamin W. Wah
Fellow, American Association for the Advancement of Science (AAAS)
Fellow, Association for Computing Machinery
Fellow, Institute of Electrical and Electronics Engineers (IEEE)
Fellow, Society for Design and Process Science
University Scholar, University of Illinois, 1989
IEEE Distinguished Visitor, 1989-1992
Fujitsu Visiting Chair Professor on Intelligence Engineering, University of Tokyo, 1992
Editor in Chief, IEEE Transactions on Knowledge and Data Engineering, 1993-1996
Associate Editor-in-Chief, Information Sciences, 1993-
McKay Visiting Professorship, University of California, Berkeley, 1994
Second Vice President, IEEE Computer Society, 1998
First Vice President Elect, IEEE Computer Society, 1998
Robert T. Chien Professor of Electrical and Computer Engineering, University of Illinois, 1999-2003
IEEE Third Millennium Medal, 2000
President, IEEE Computer Society, 2001
Sun Yun-suan Honorary Chair Professor, National Tsinghua University, 2002
Raymond T. Yeh Life Time Achievement Award, Society for Design and Process Science, 2003
Franklin Woeltge Professor of Electrical and Computer Engineering, University of Illinois, 2004-
1st Prize, Suboptimal Temporal Metric Track, 4th Intel Planning Competition, 2004
Best Paper Award, IEEE International Conference on Tools for Artificial Intelligence, 2005

Martin Wong
Institute of Electrical and Electronics Engineers (IEEE)
CAD Transactions Best Paper Award, 2000
IBM Faculty Award, 2000, 2004
David Bruton Centennial Professor in Computer Sciences, University of Texas at Austin, 2001
Best-of-20-Years ICCAD Paper, 2002
IEEE Distinguished Lecturer, 2005-